Hydrodynamics and transport processes on the historical landscape: geomorphic control of functional complexity and implications for restoration

November 18, 2009

Chris Enright

DWR

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Listed species challenges

The POD suggests a stressor train wreck:

- Contaminants
- Toxic algae
- Water project exports
- Invasive plants and animals
- Low primary production estuary
- **Landscape-scale habitat loss**

Changes we can anticipate (e.g. CASCaDE)

- Levees will fail
- Climate change (flood, drought, runoff timing)
- Water temperature increase
- Land subsidence continues
- Seasonal salinity change (more variable?)
- Quagga and Zebra mussels at least
- Unknown new contaminants and invasives
- New Delta plumbing
- Sea level rise
- **Restore tidal connections to diked land**

In this workshop, the focus is ecosystem restoration because

CONCEPTUAL MODEL:

- Tidal restoration provides ecosystem function support: food, subsidies, refuge, ontogeny

∴ It will help conserve listed species

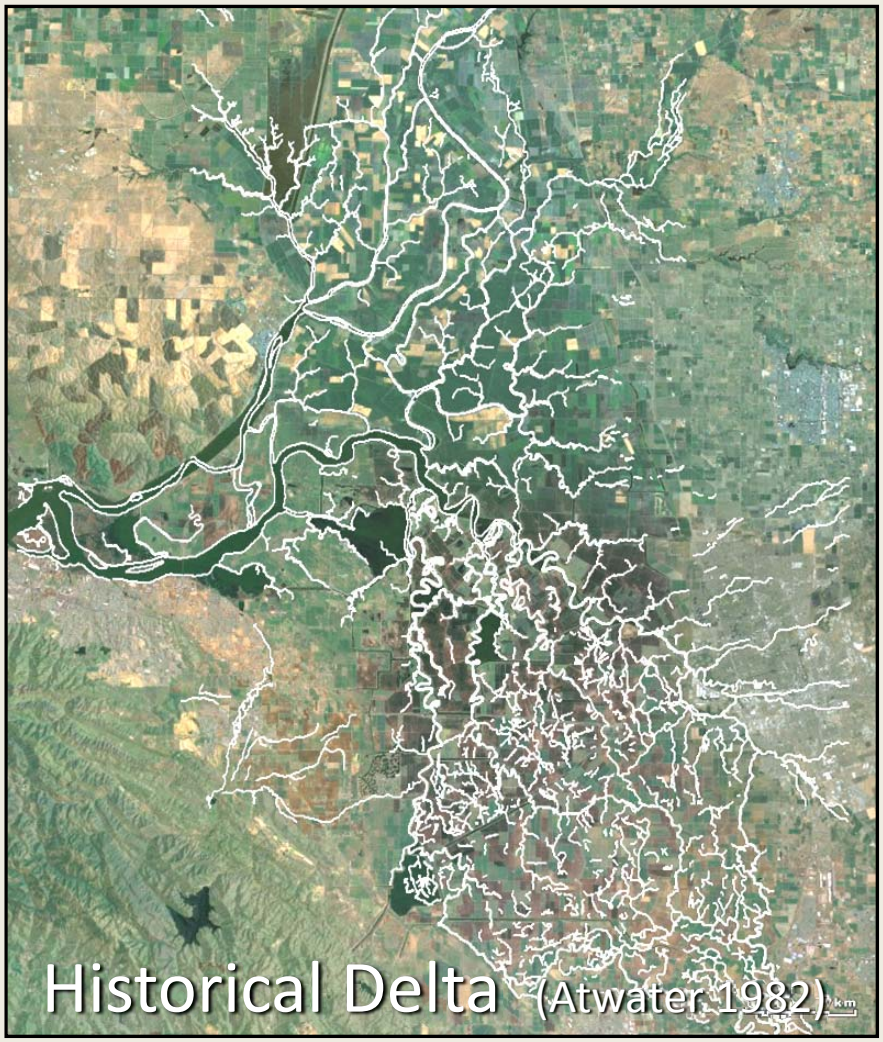
This talk

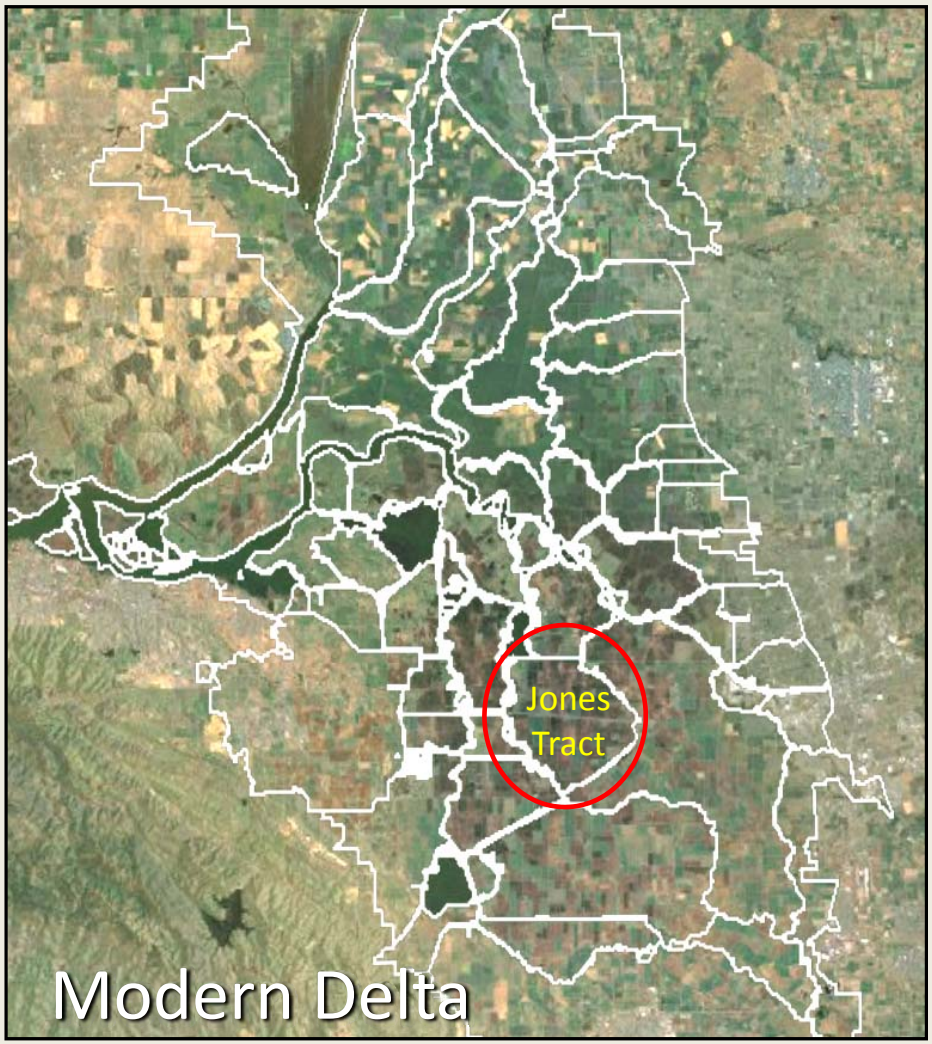
1. Native fishes evolved in response to the historical landscape– structure, process, and function.
2. Compare historical and modern Delta: To fish, the delta was both bigger *and* smaller.
3. Historical Delta was spatially gradient rich: *the distance to different was small*
    a) Structure and "realized" function
    b) transport timescales
    c) temperature as f(structure)
4. Understanding the historical "spatial pattern" informs restoration strategies

2. To a mobile organism,

the historical Delta was much bigger, ***and***,

the historical Delta was much smaller

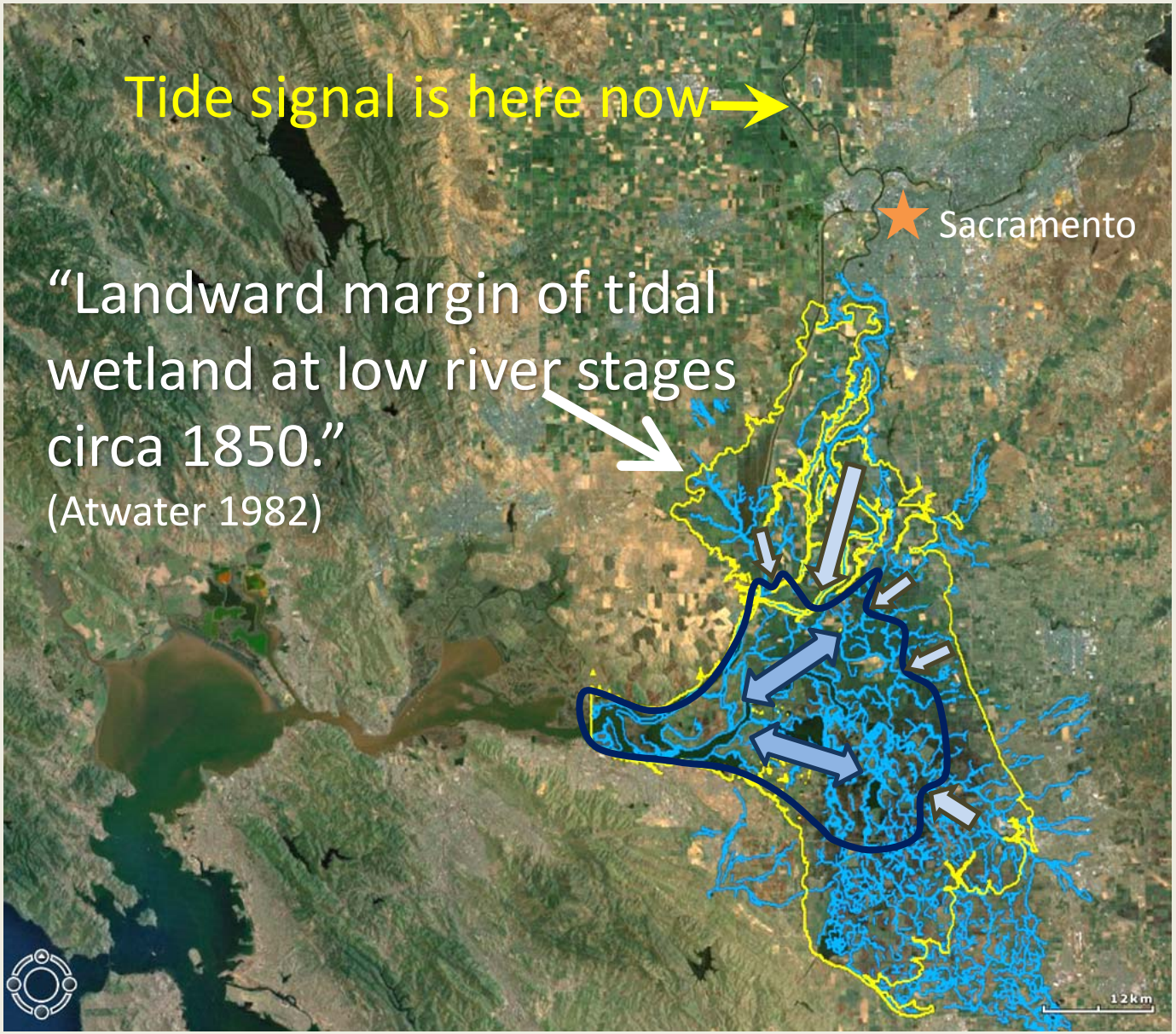




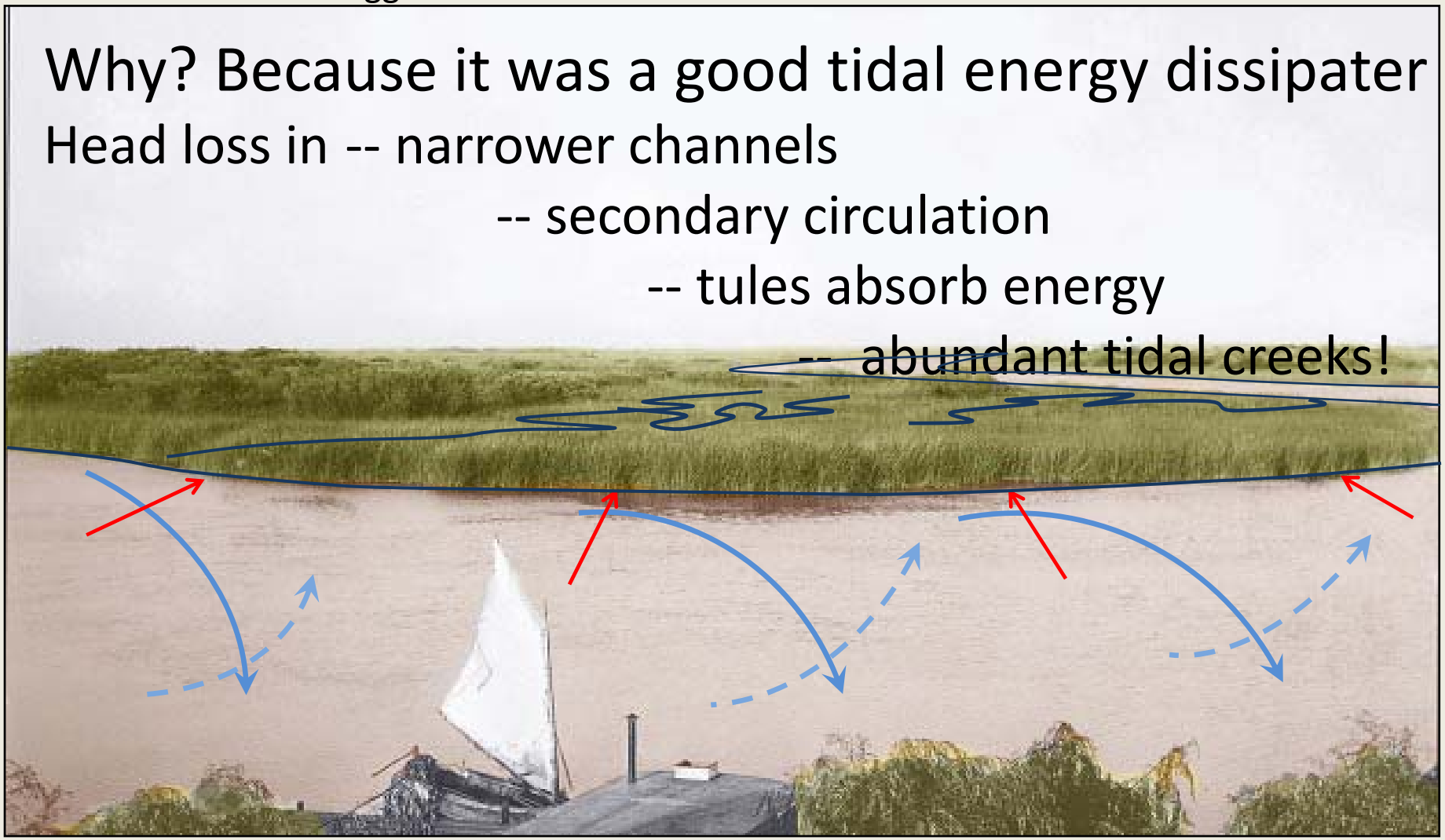
Historically, the tidal Delta scaled differently: bigger and smaller

Extent of tidal influence would be deeper into the delta

Riverine bi-directional tide would be smaller



2. Historical Delta was bigger *and* smaller

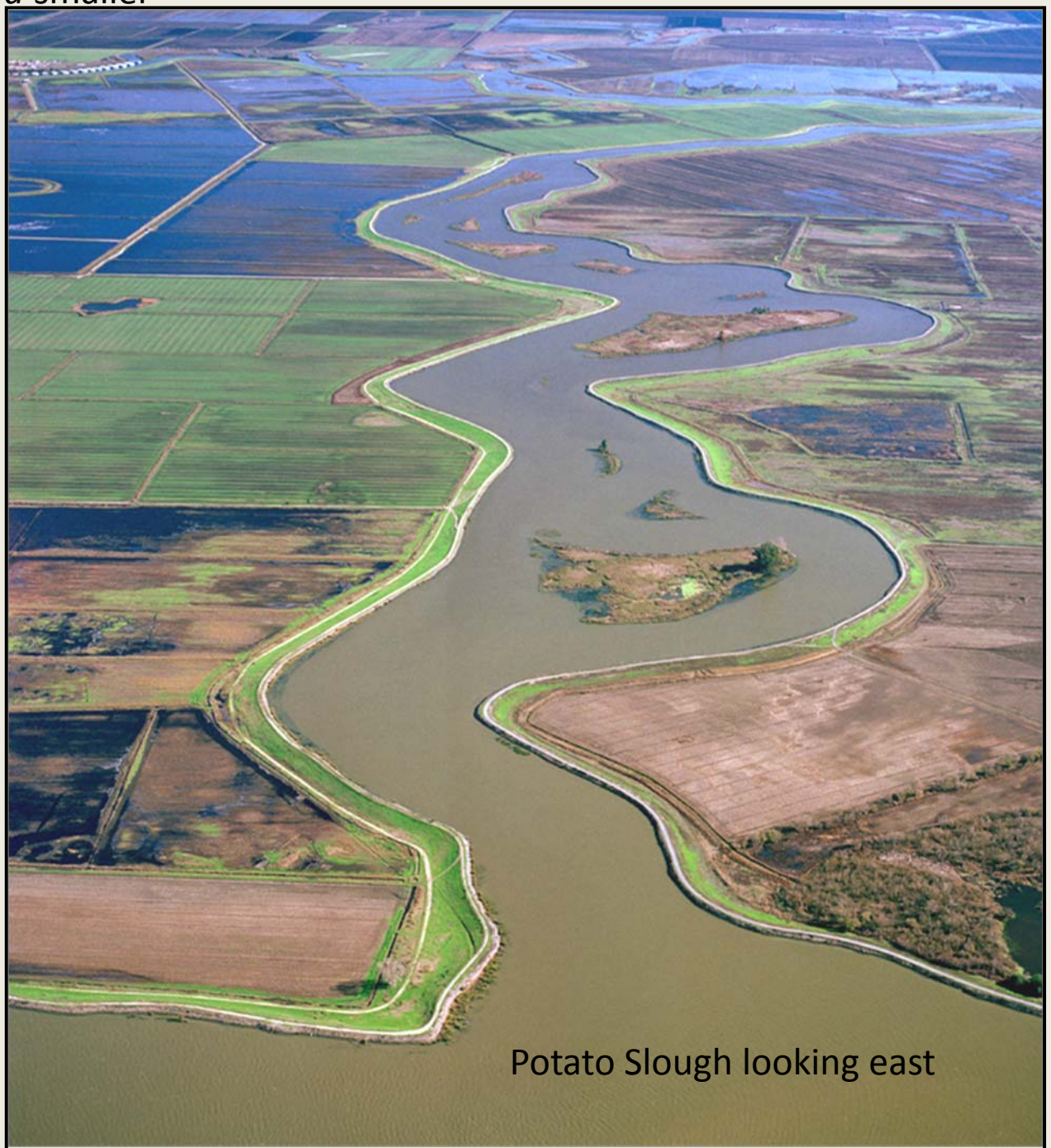


"A view of delta in natural wetland state covered with tules unsuitable for farming."

From: "DOWN RIVER
Sacramento to the Golden Gate
A Pictorial Record:
1840-1940"
(No date on the photo)

2. Historical Delta was bigger *and* smaller

Modern Delta: Far less energy dissipation. It's more like a canal system.



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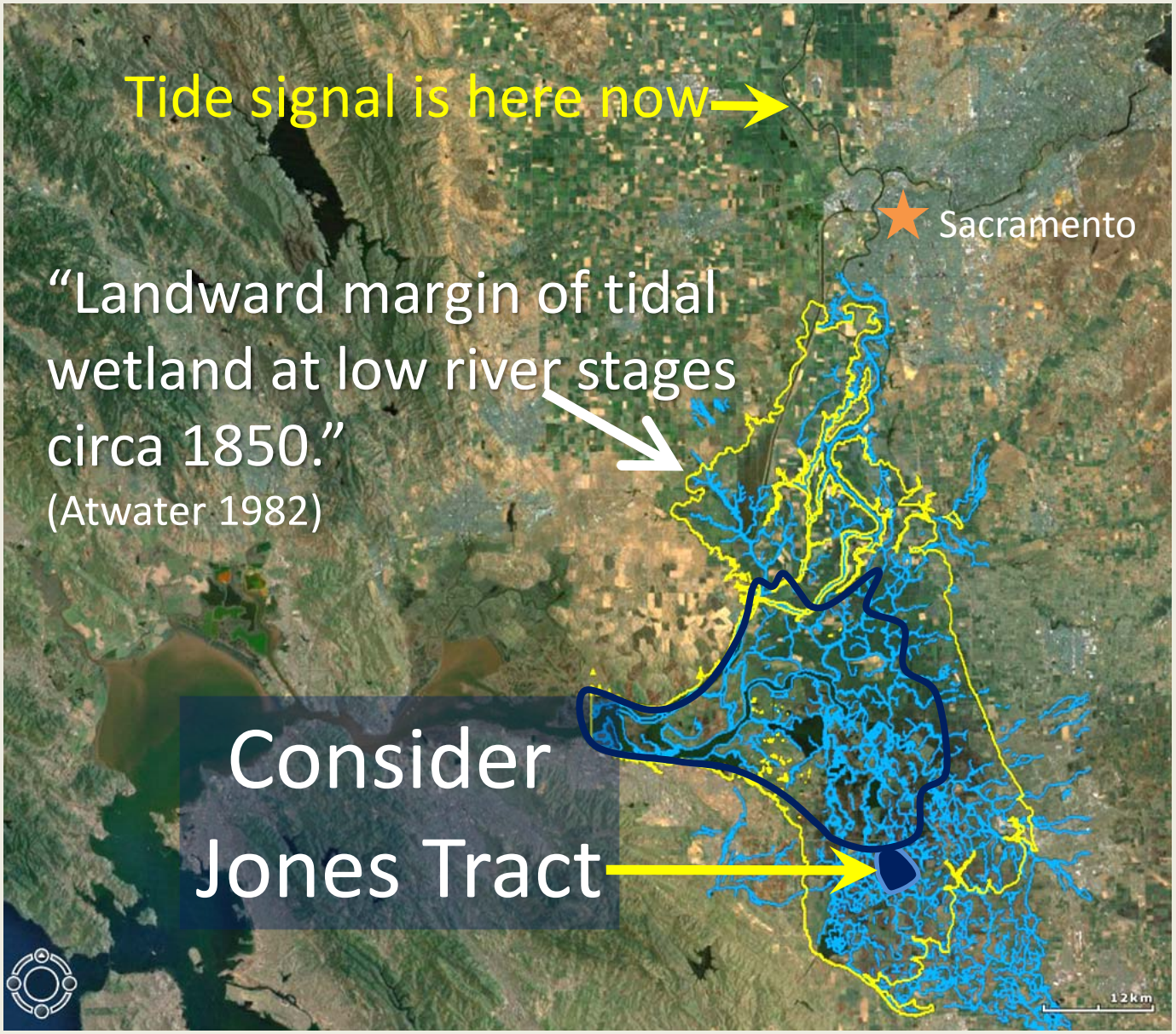
Historically, the tidal Delta scaled differently: bigger and smaller



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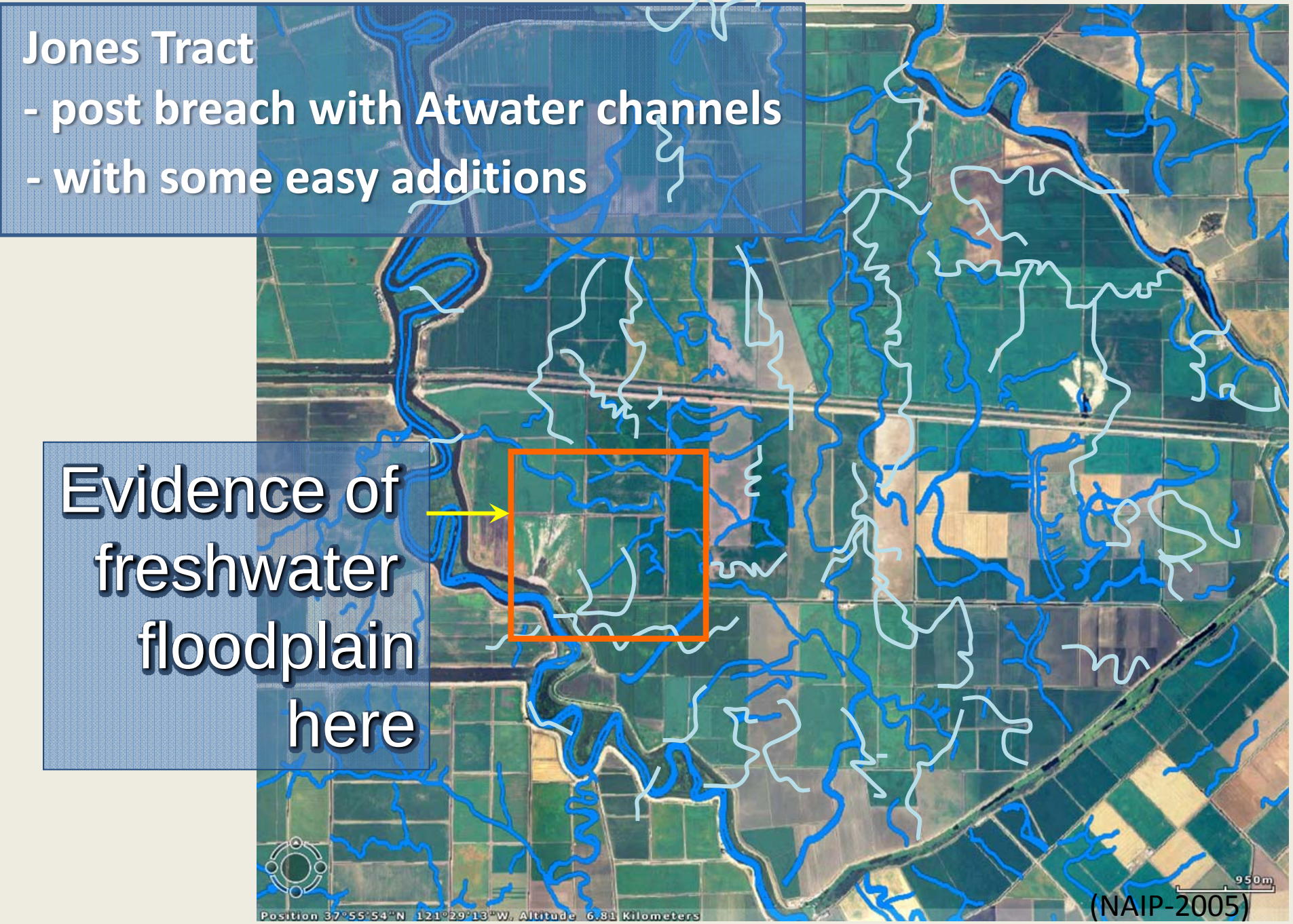
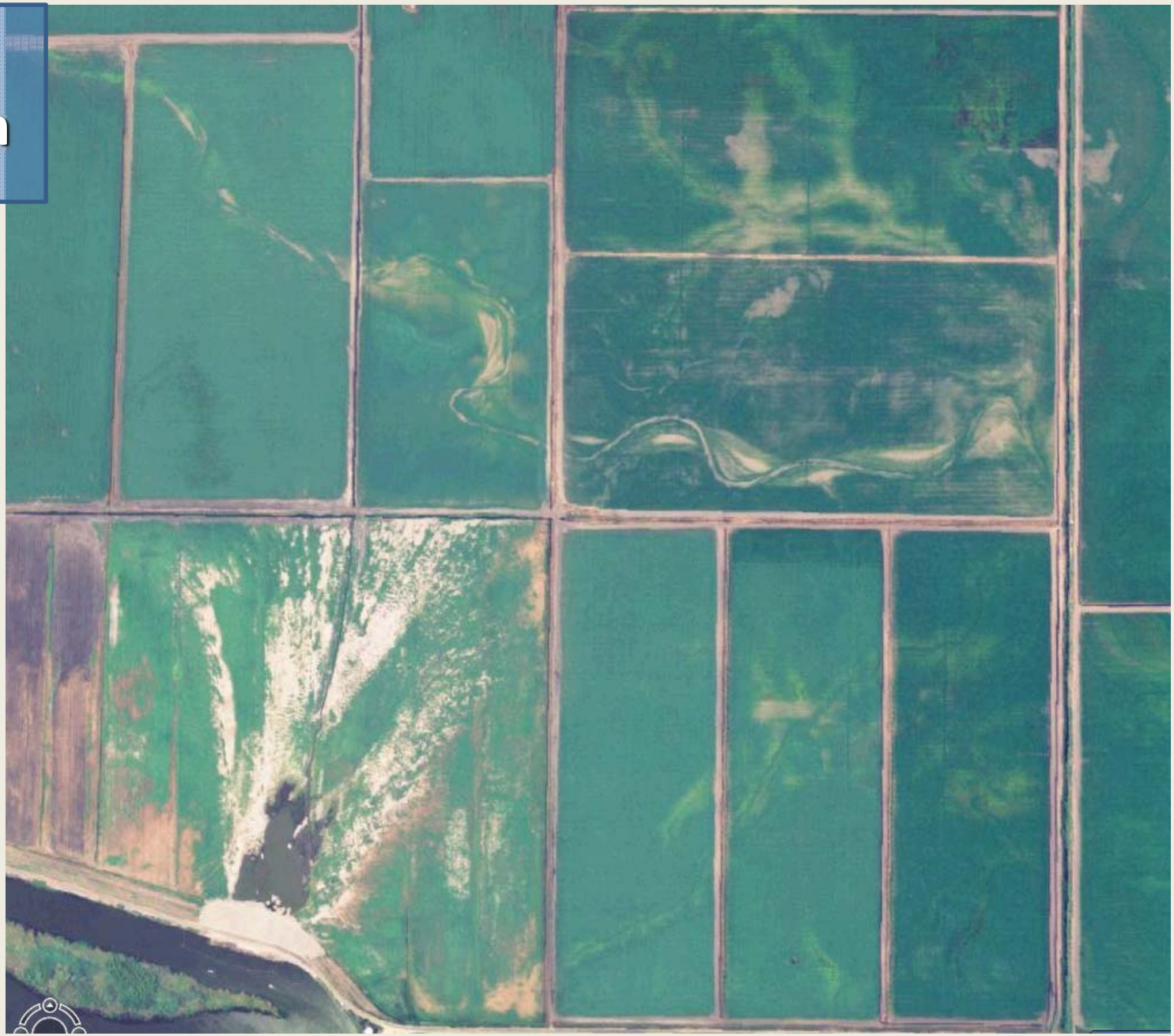


2. Historical Delta was bigger *and* smaller

Jones Tract - post breach



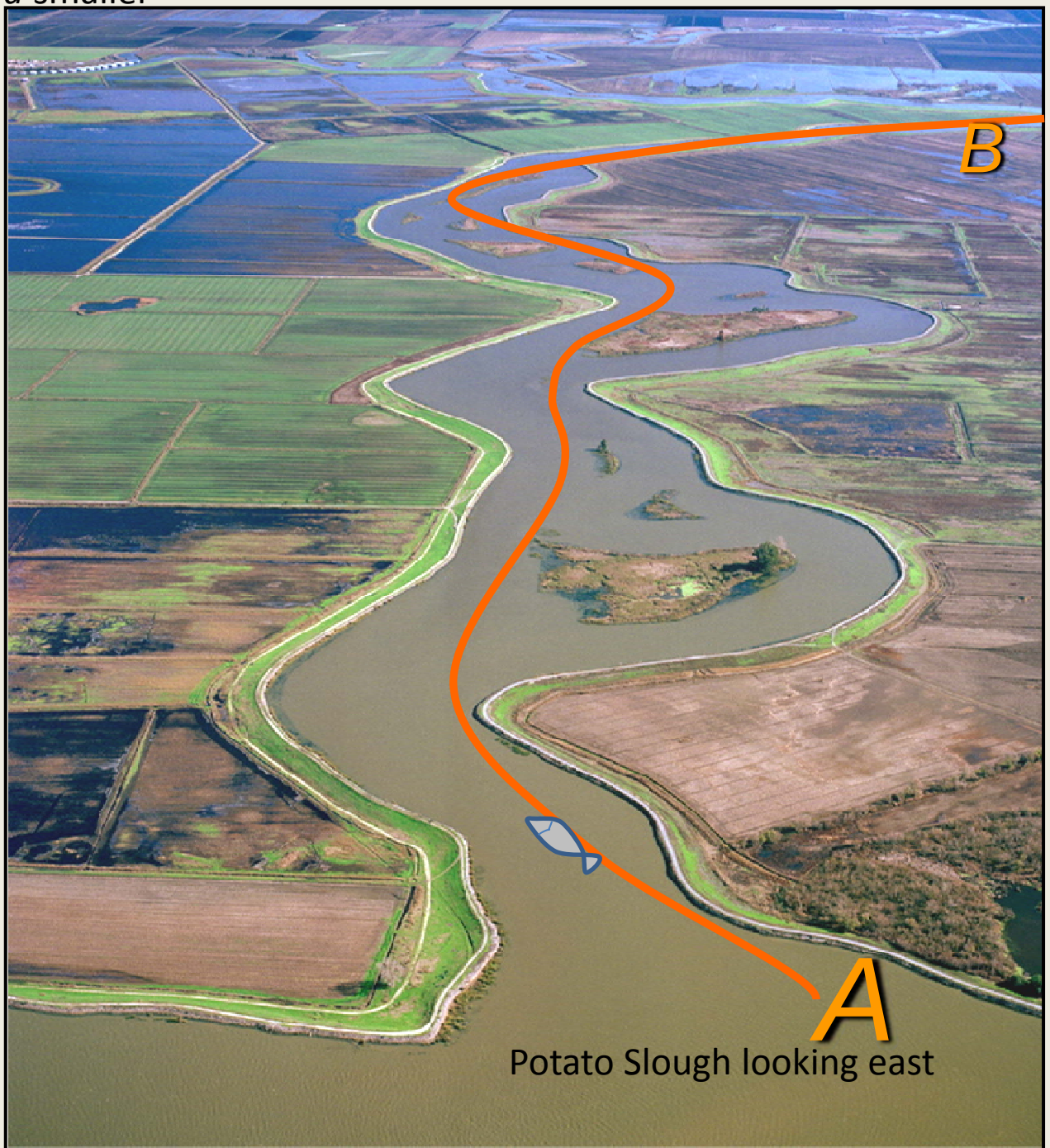
(NAIP-2005)

Historical tidal channels were narrow and long, while modern delta is wide and short (A to B)

- Modern levees set back
- Meanders cut off

2. Historical Delta was bigger *and* smaller

Modern Delta is a straight shot for fish



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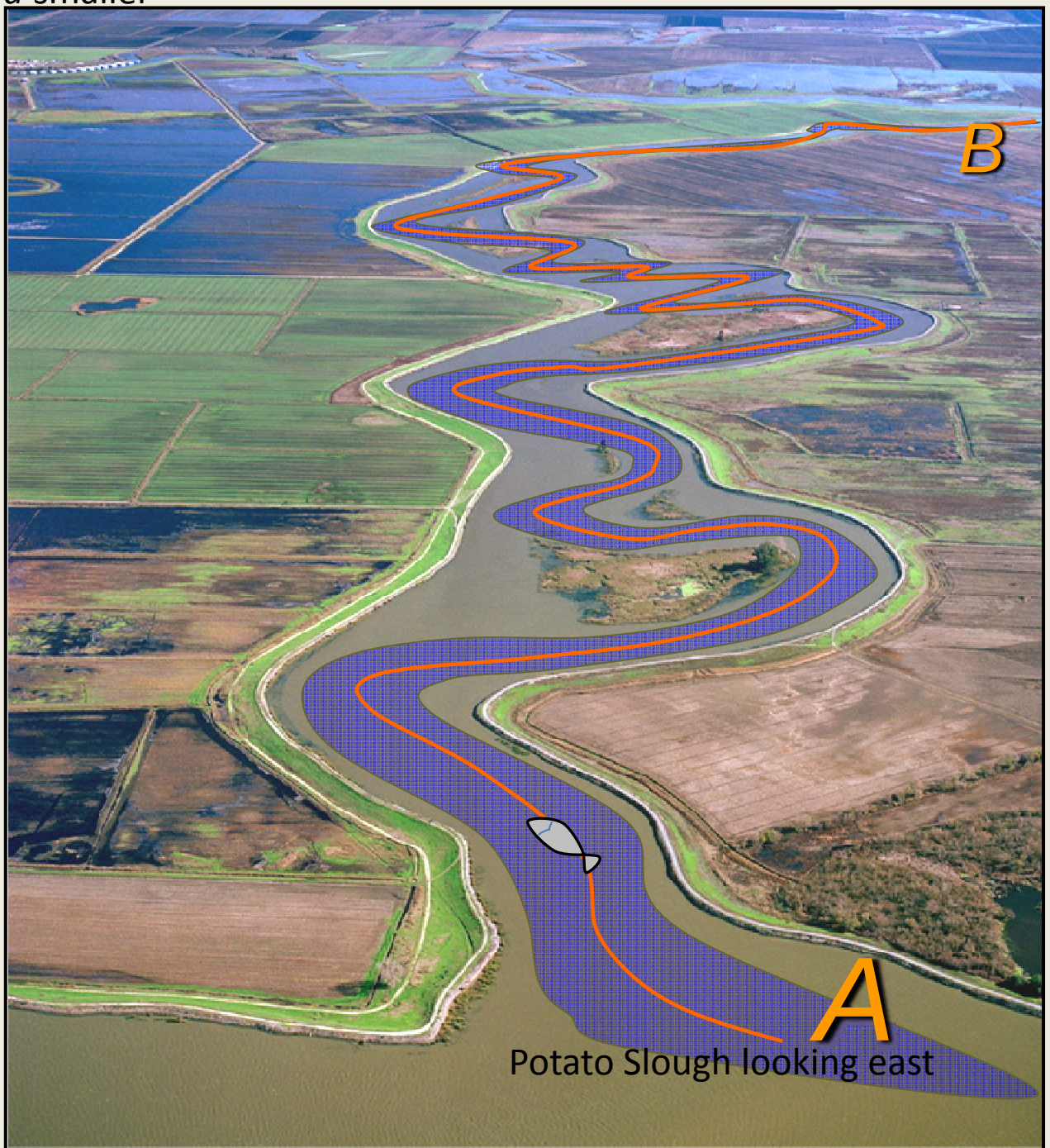
2. Historical Delta was bigger *and* smaller

Historical Delta was narrower and longer



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2. Historical Delta was bigger *and* smaller

Historically, tributaries were separate systems; Modern Delta is a short circuit

Historical Delta is bigger *and* smaller

Historical Delta "bigger"

- Long sinuous channels
- Waaaay more "edge"
- Long geographical distances A to B

Historical Delta "smaller"

- ↓ geographical tidal extent
- Narrower channel width
- ↓ area of bi-directional tide
- Smaller tidal excursion/range
- River influence penetrated

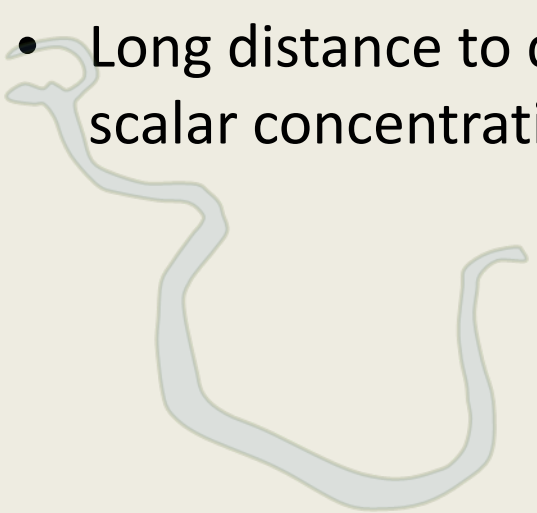
Modern Delta is bigger *and* smaller

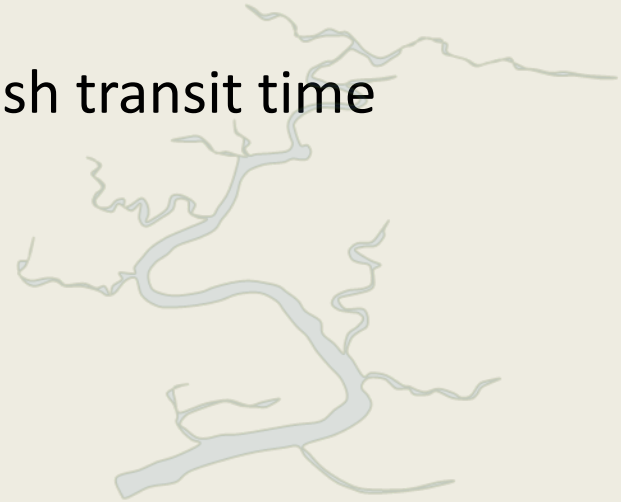
Modern Delta "bigger"

- ↑ geographical tidal extent
- ↑ bi-directional tidal area
- Longer tidal excursion
- Bigger tidal range
- Wider channels (canals)
- Long distance to different scalar concentration

Modern Delta "smaller"

- Levees "shortened" reach distances A to B
- Loops and channel cuts short circuit transit A to B
- Far less channel/slough edge
- Short fish transit time





3. Delta was spatially gradient rich: *the distance to different was small.*

Examples:

a) Structure and “realized” function

b) Transport timescales

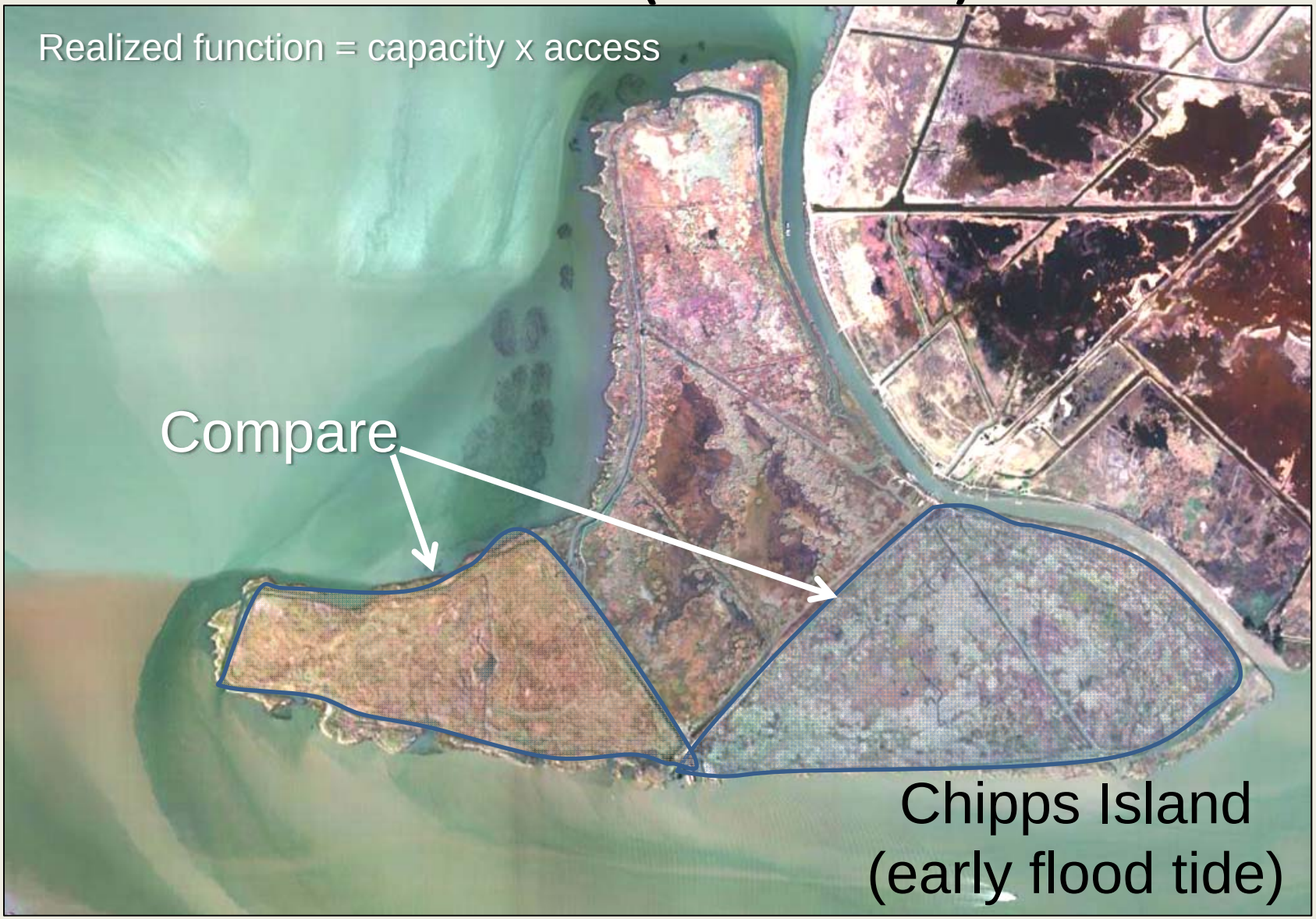
c) Temperature as f(structure)

3a. Structure and (realized) function

- Simenstad *et al.* 2000:

Realized function	=	capacity	x	access
Survival		phyto production		edge as ecotone
Growth		insect production		edge: patch area
Reproduction		zoop production		"hot spots" (Kneib '97)
		temperature refuge		patch size/shape
		cover options		corridors

3a. Structure and (realized) function



3a. Structure and (realized) function

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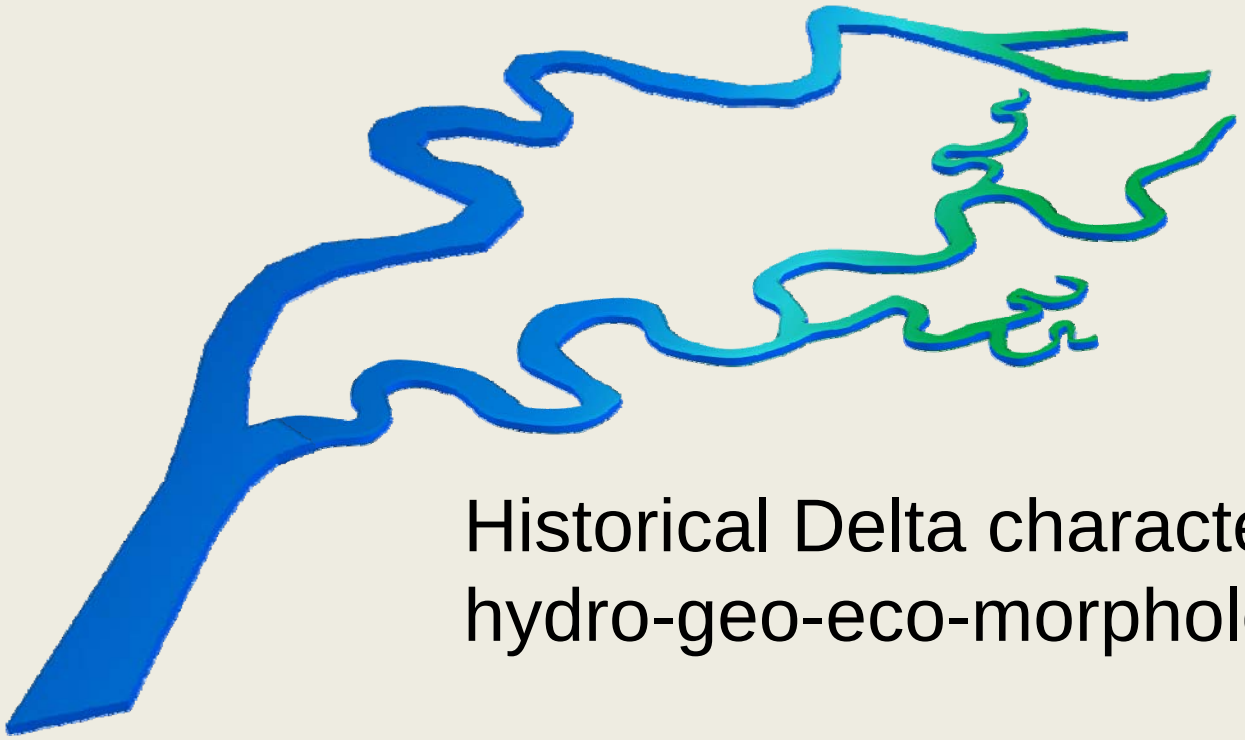
3a. Structure and (realized) function
Turbidity “front” off Chipps Island
Early flood tide
6-29-09
Photo by
Stuart Siegel

3b. Compare transport timescales

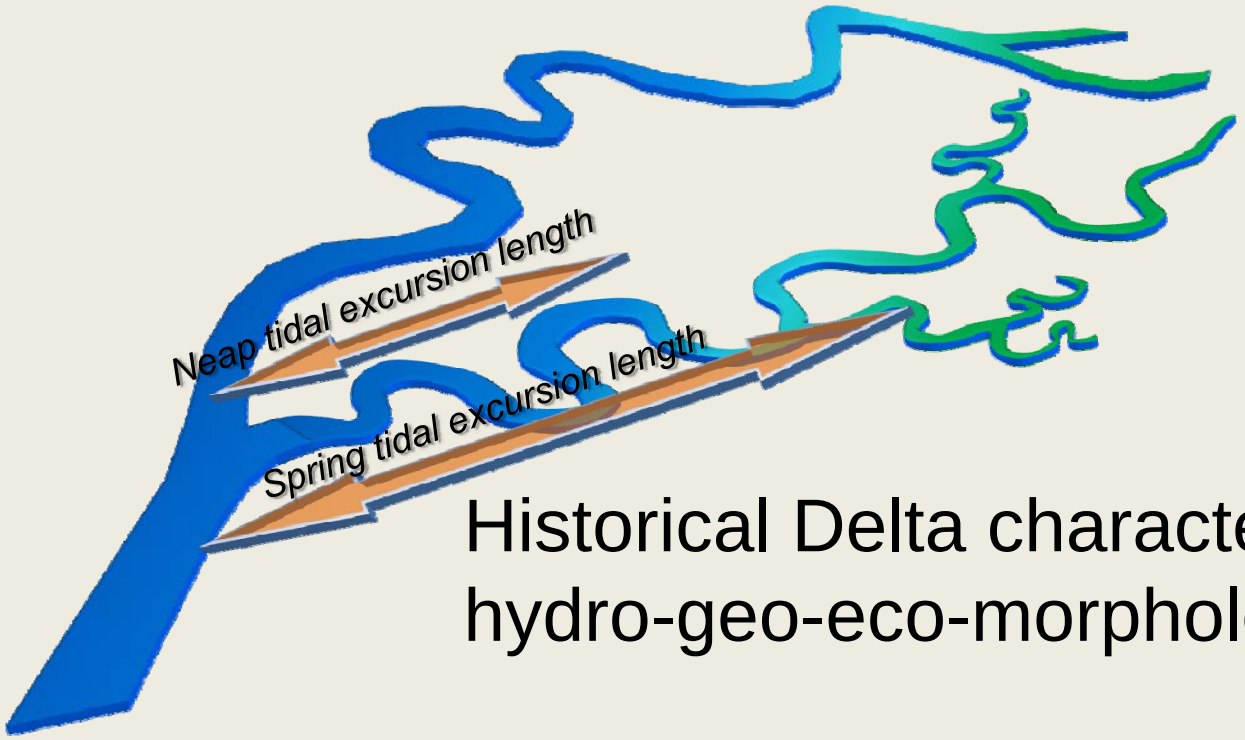


Low order
tidal creeks
(~autotrophic)

Historical Delta characteristic
hydro-geo-eco-morphology

Deep Slough
(~heterotrophic)

3b. Compare transport timescales



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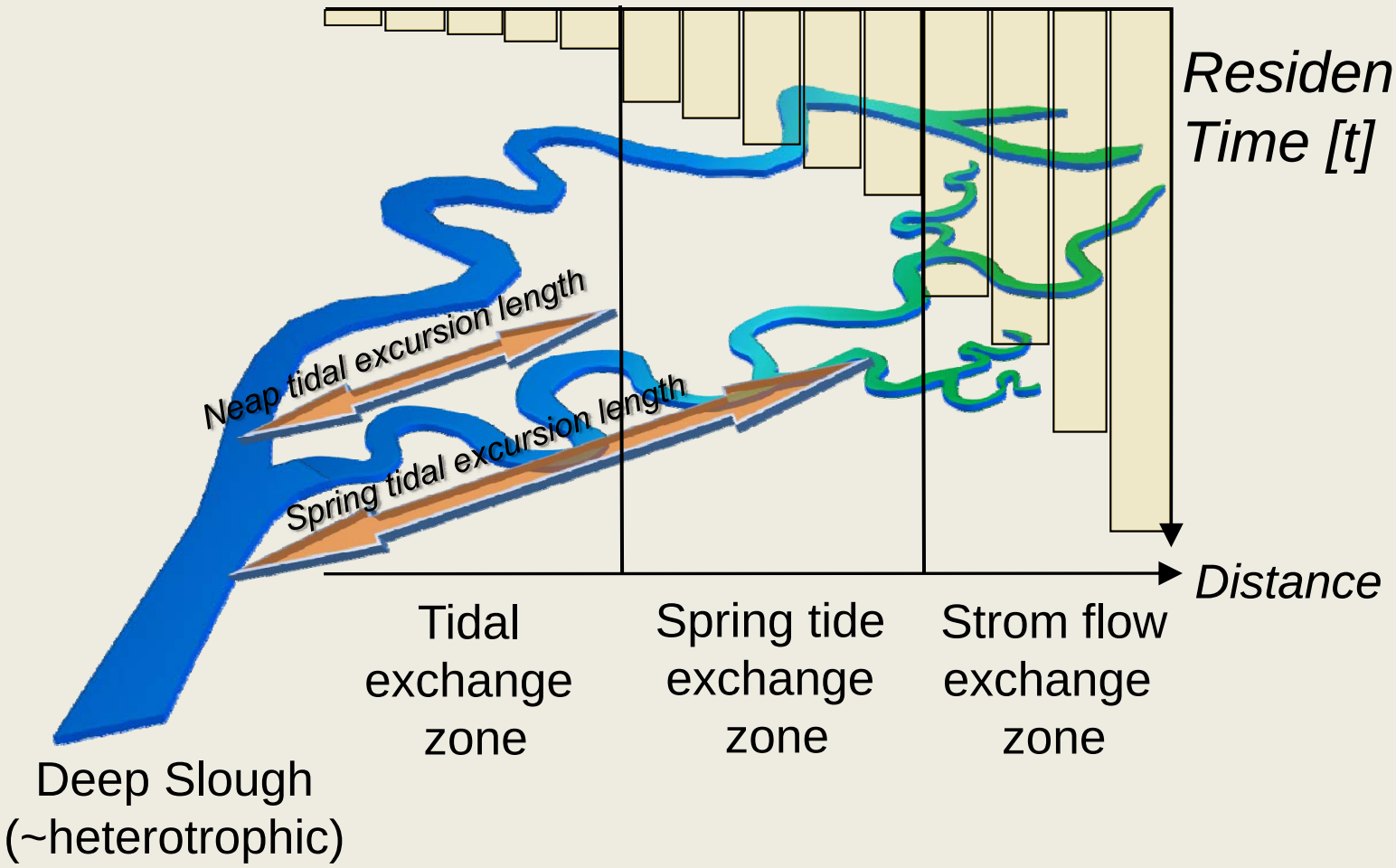

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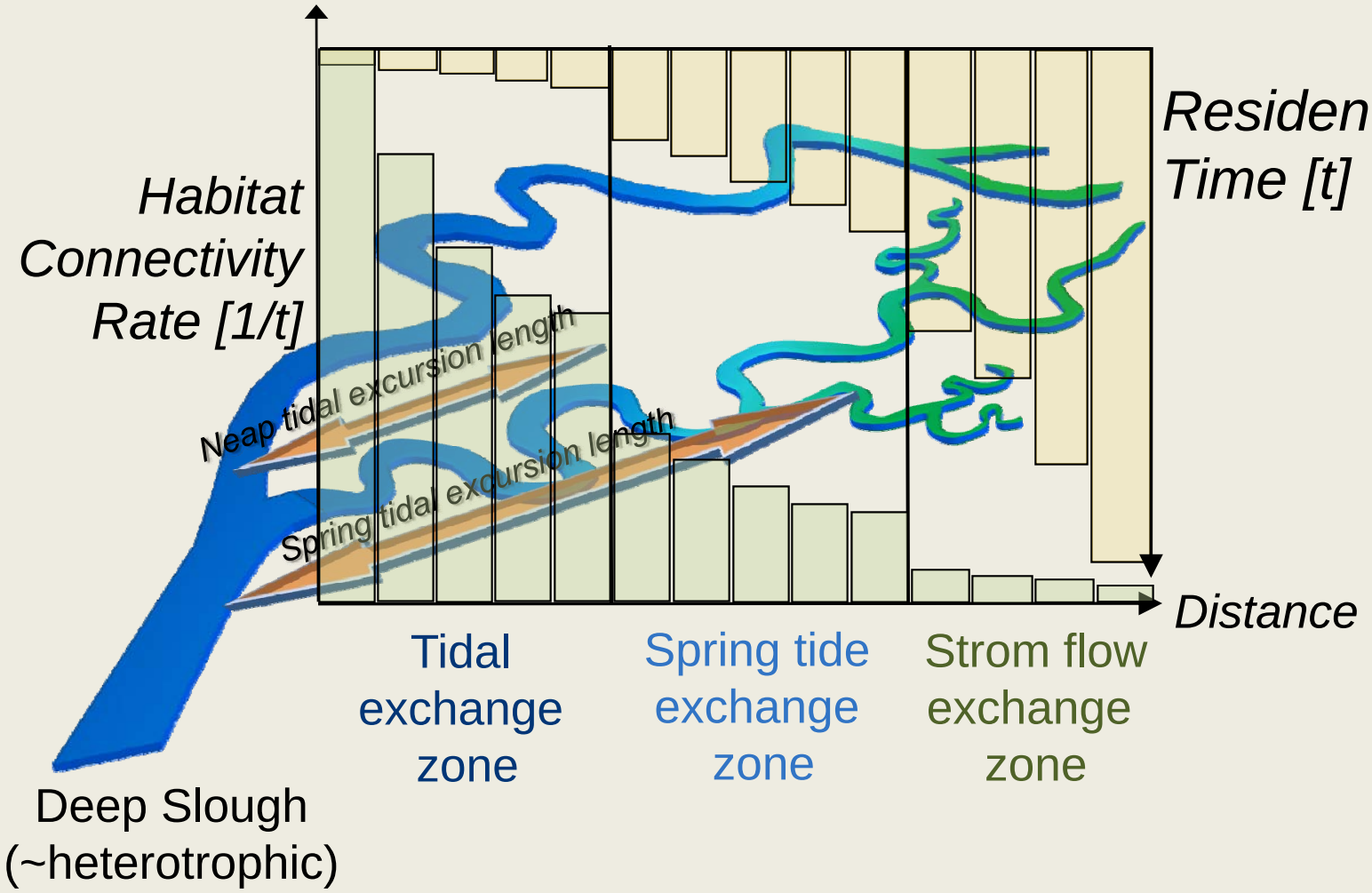

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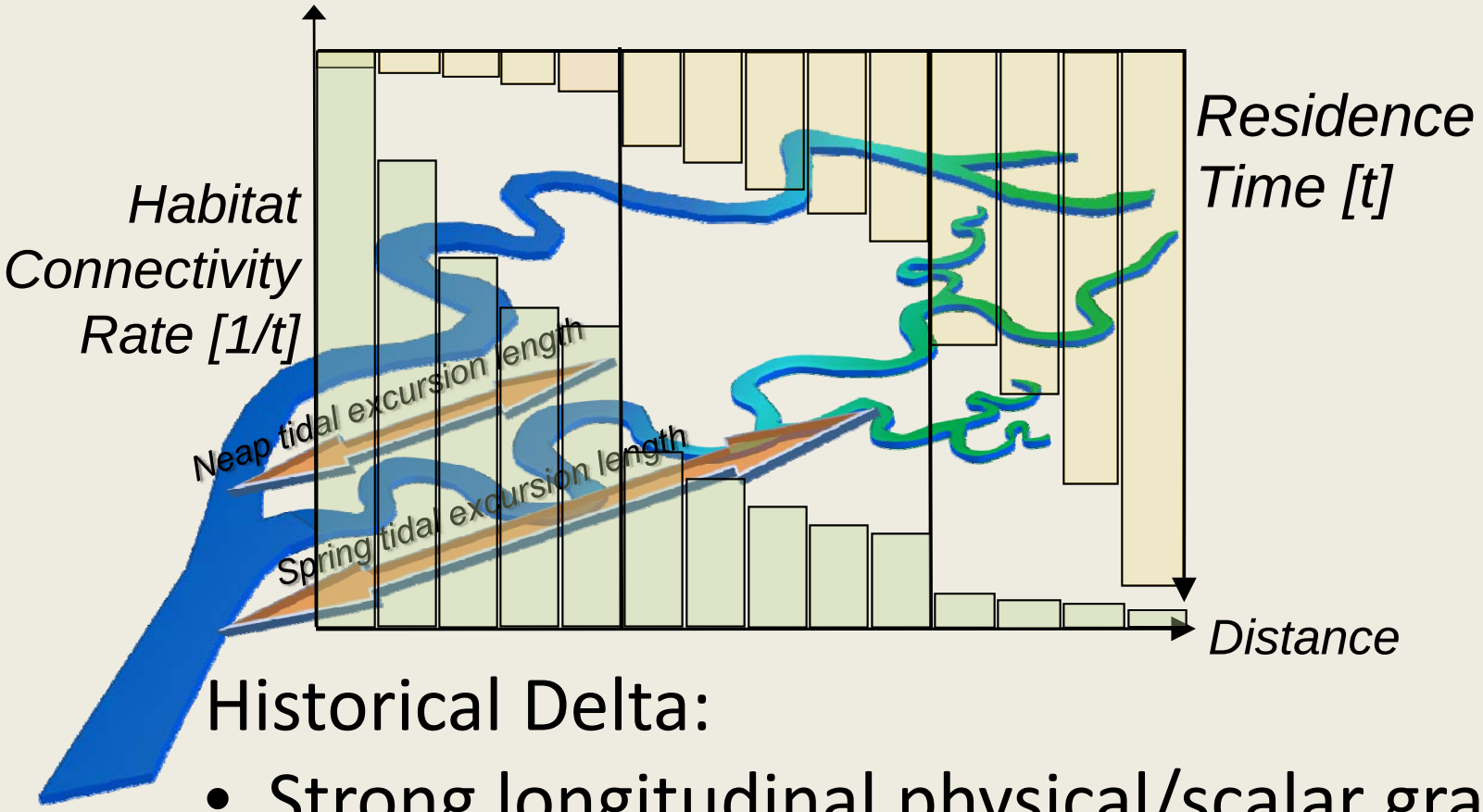
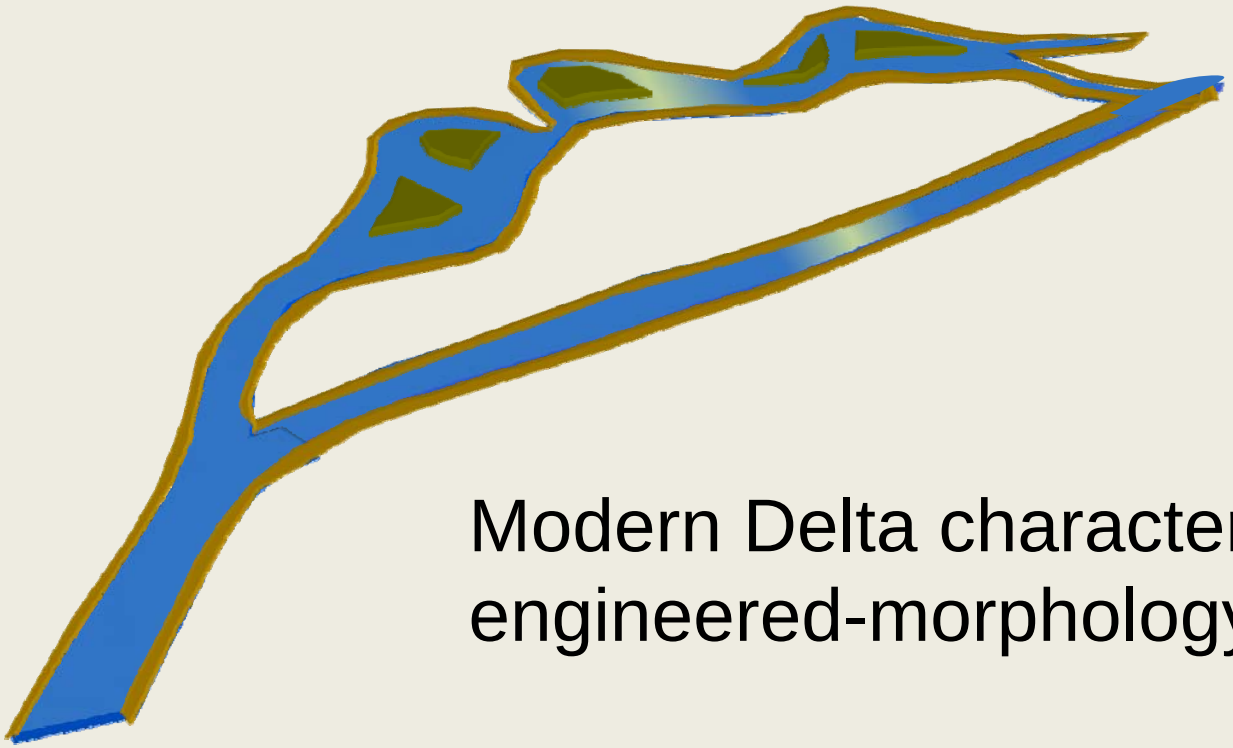


Historical Delta:

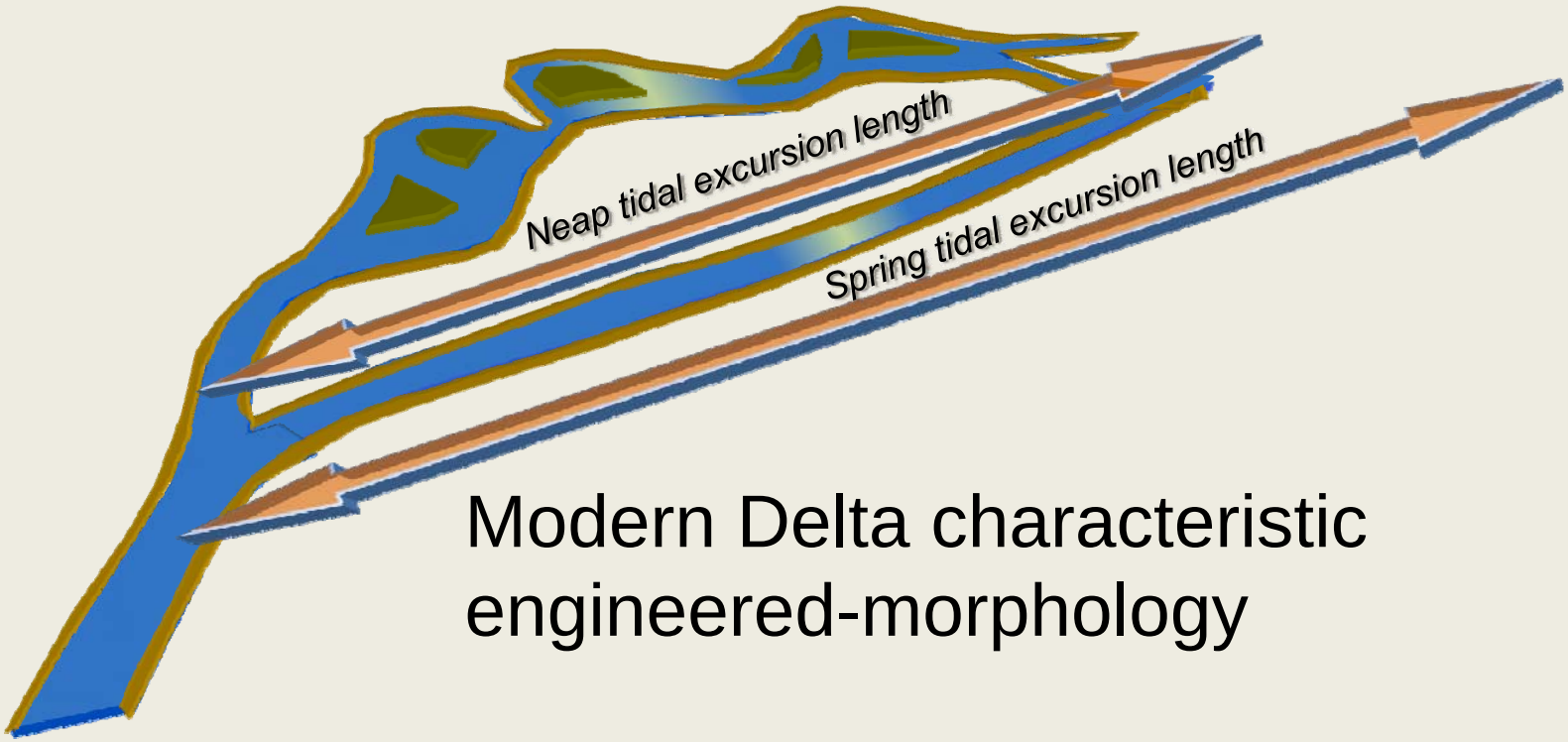
- Strong longitudinal physical/scalar gradients
- Connectivity is **f**(tide strength)
- Large terrestrial connectivity and exchange
- *Distance to different is small*

3b. Compare transport timescales



Modern Delta characteristic engineered-morphology

3b. Compare transport timescales



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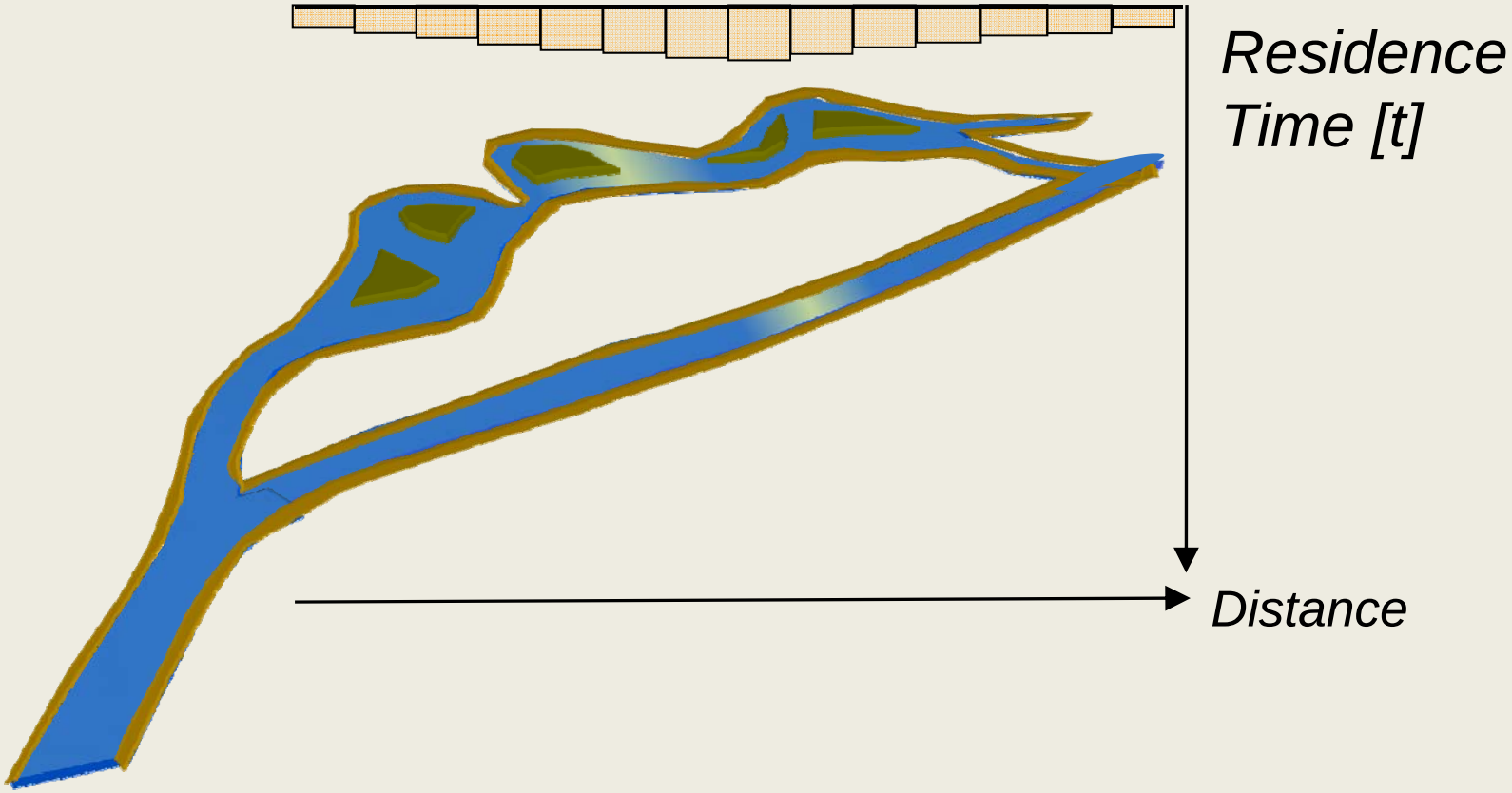

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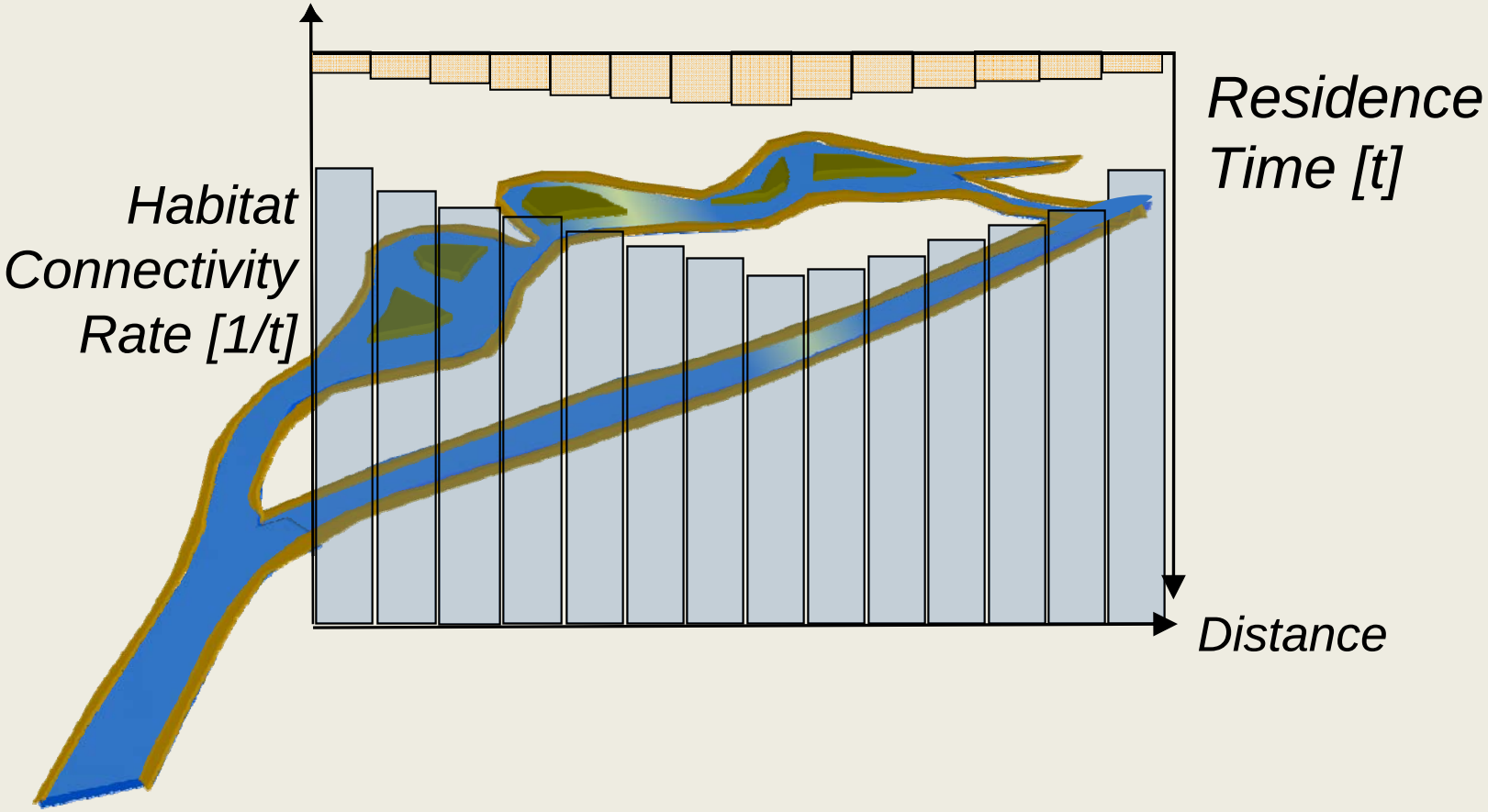

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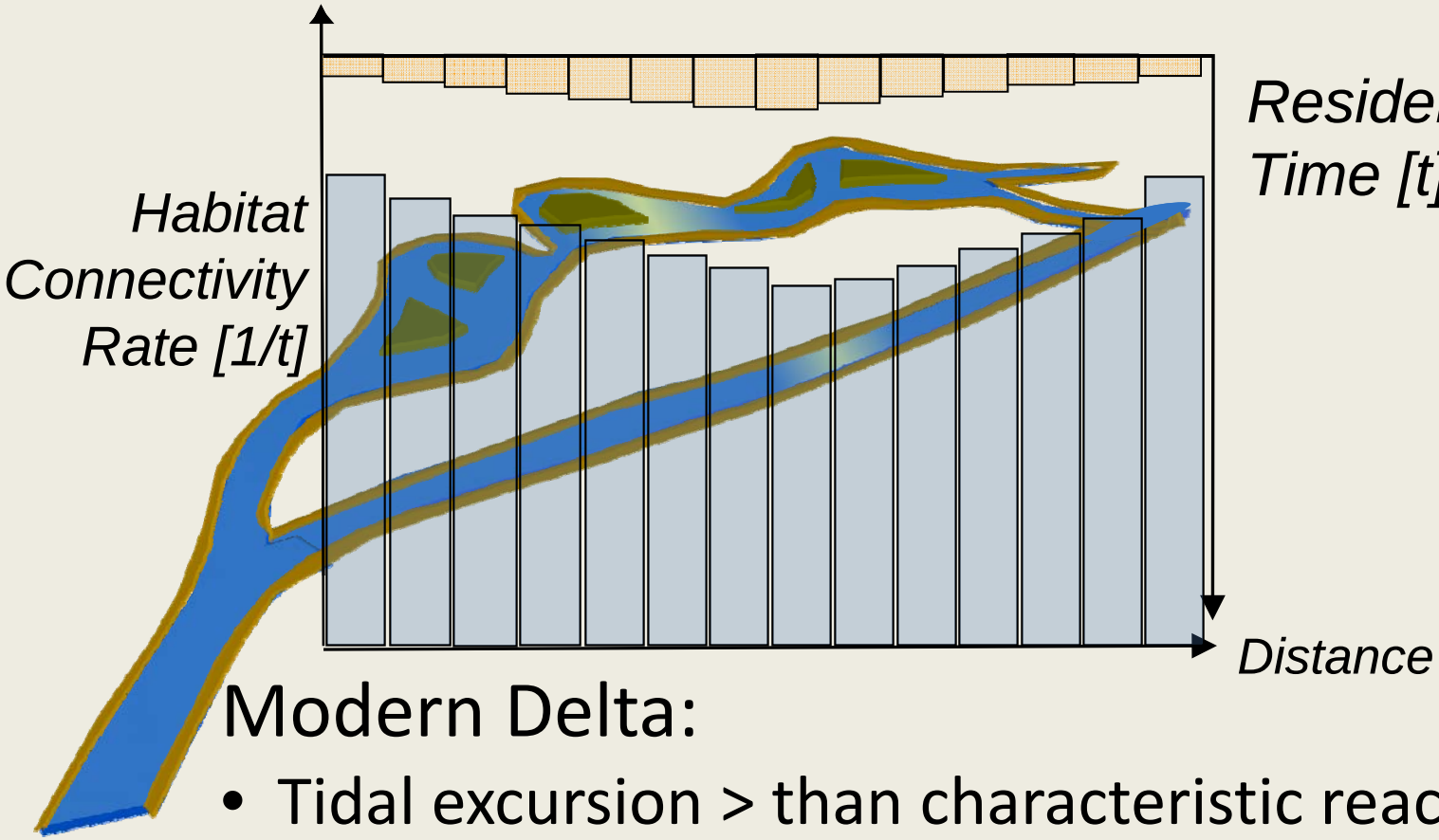
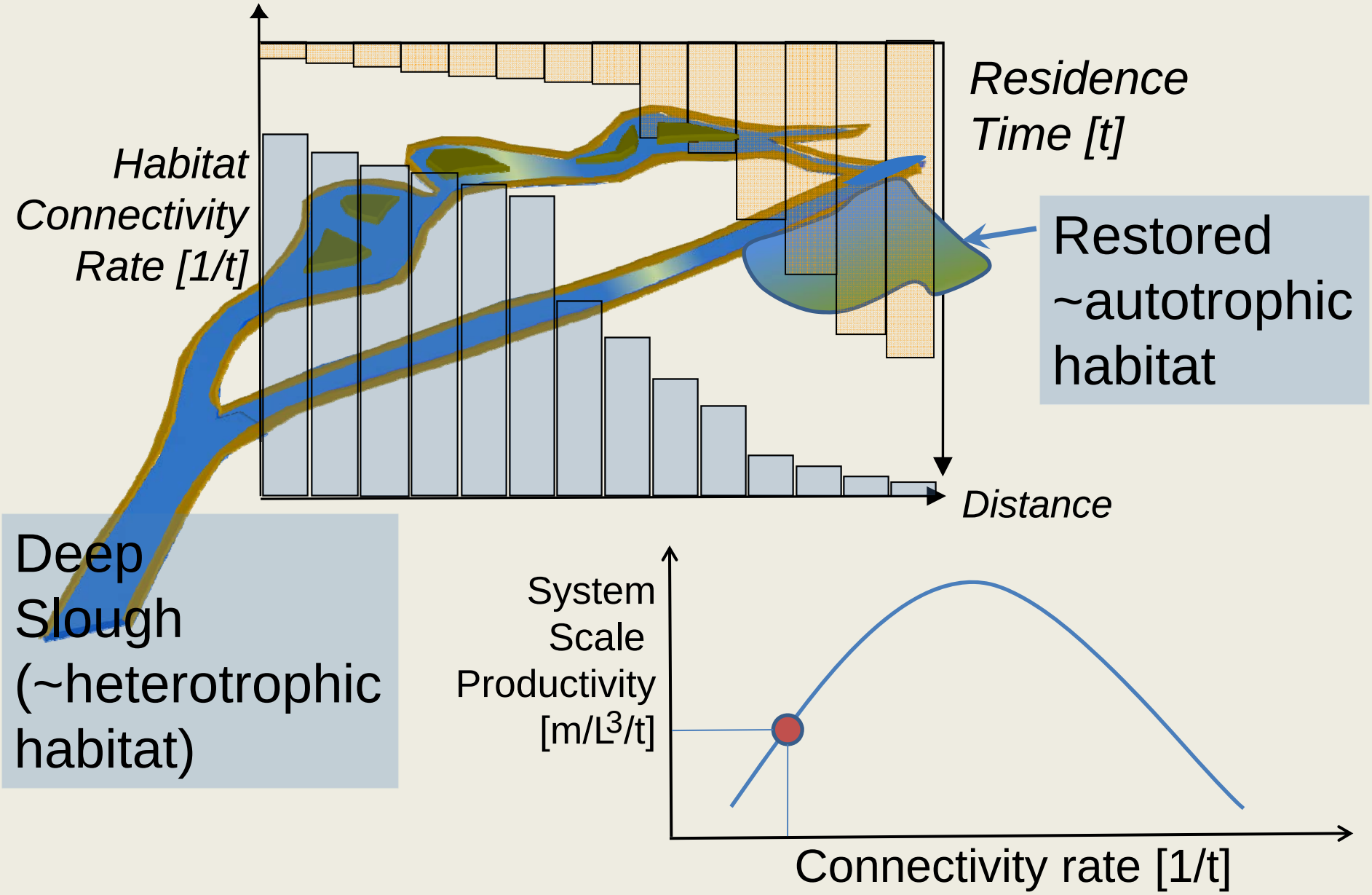


Modern Delta:

- Tidal excursion > than characteristic reach length
- Effectively shorter channel reaches
- Weak longitudinal physical/scalar gradients
- Connectivity not **f**(tide strength)
- No terrestrial connectivity/exchange

3b. Compare transport timescales



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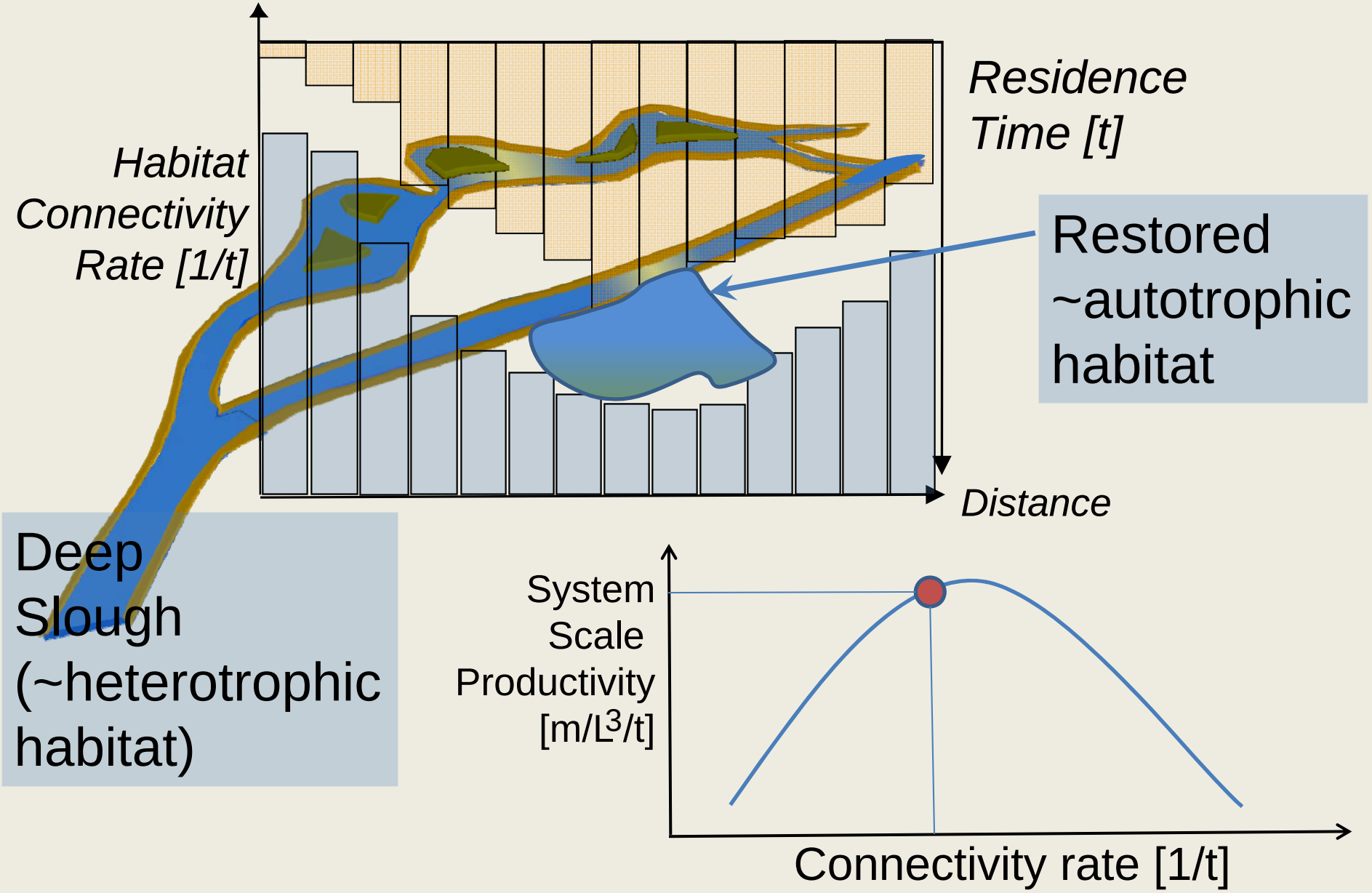

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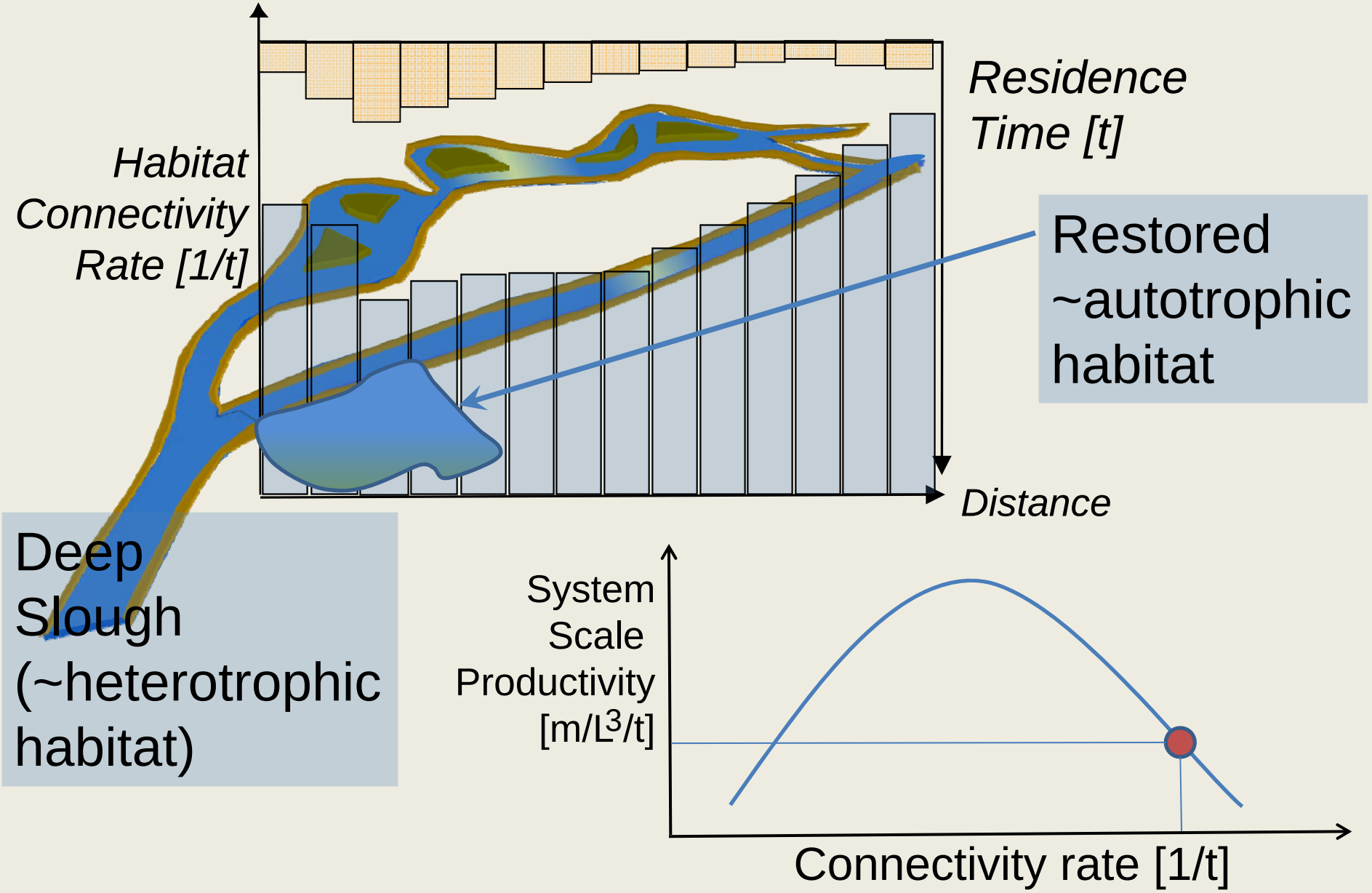

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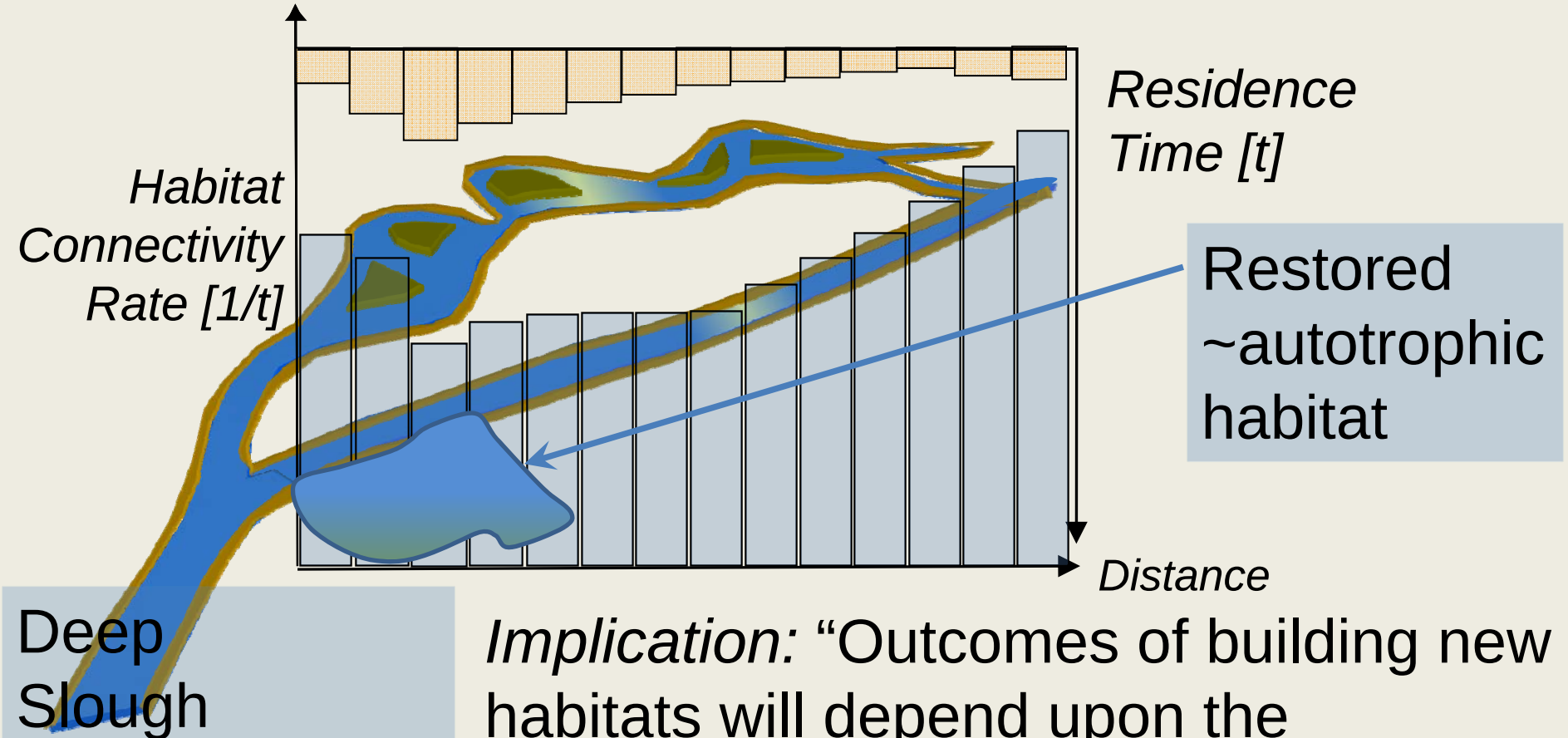
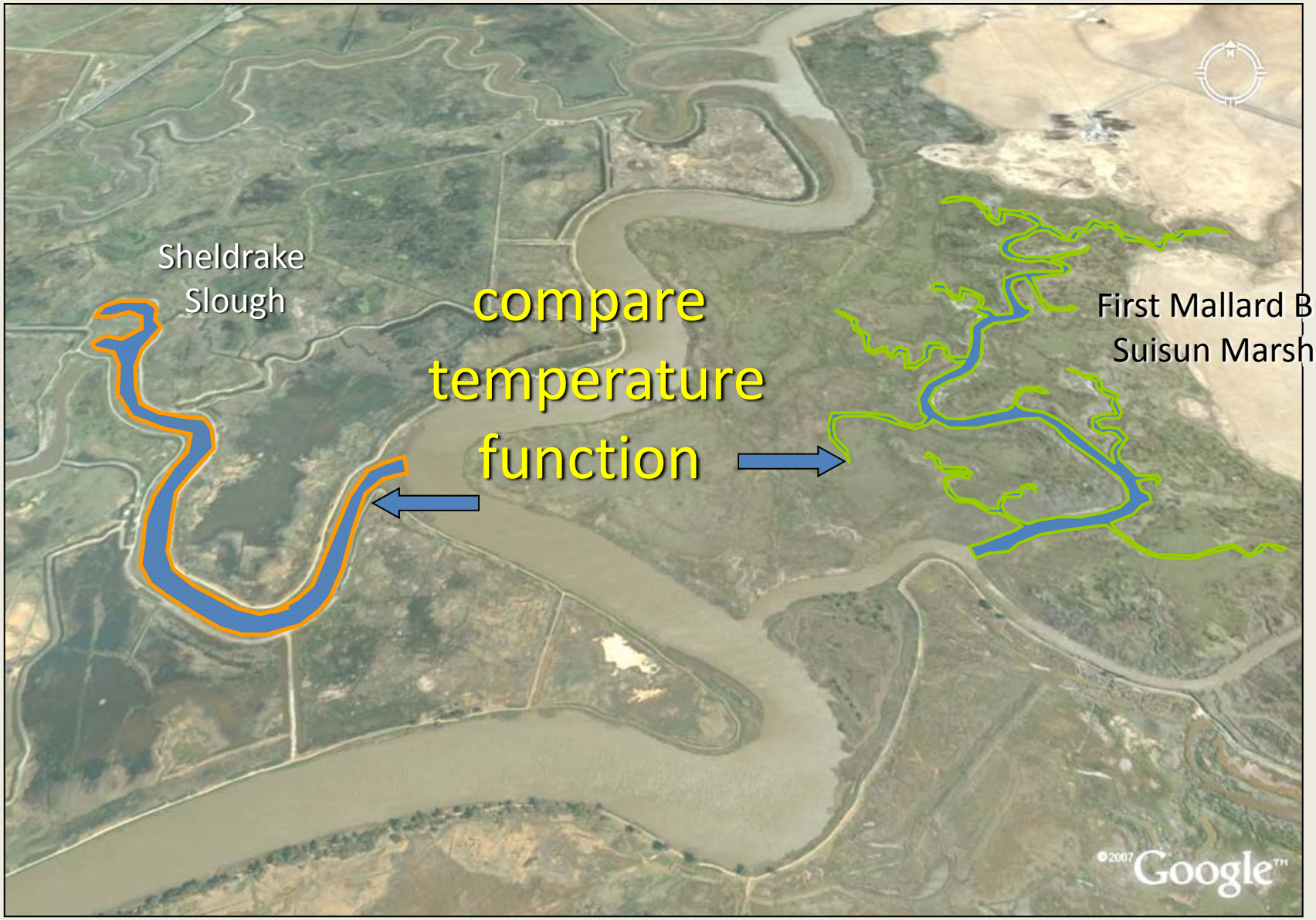


Restored ~autotrophic habitat

Deep Slough (~heterotrophic habitat)

Implication: "Outcomes of building new habitats will depend upon the landscape configuration of those habitats and, in particular, how rapidly they exchange water, solutes, and biota with connected habitats." (J.Cloern)

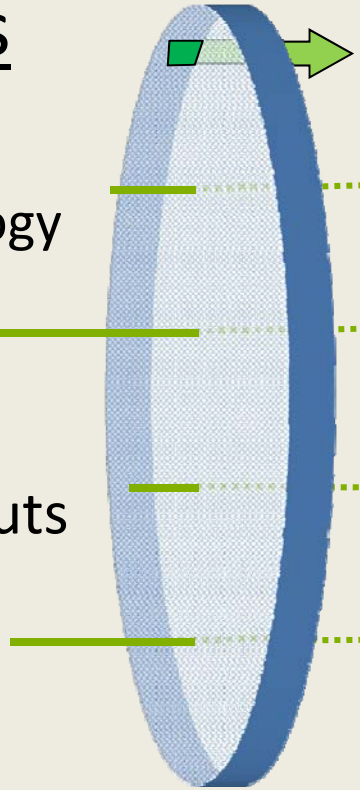
3c. Temperature as f(structure)



Structure influences function

Geomorphology "filters" estuarine drivers

Geomorphology
(Like a Filter)



Drivers
(forcing)

- Meteorology
- Tides
- River inputs

Linkages
(processes)

- Advection
- Dispersion
- Gravitational Circulation
- Sedimentation

Outcomes
(Chemical/Biological Habitat Characteristics)

Gradients of

- Residence time
- Salinity
- Temperature
- Sediment
- Biota
- Toxics
- etc.

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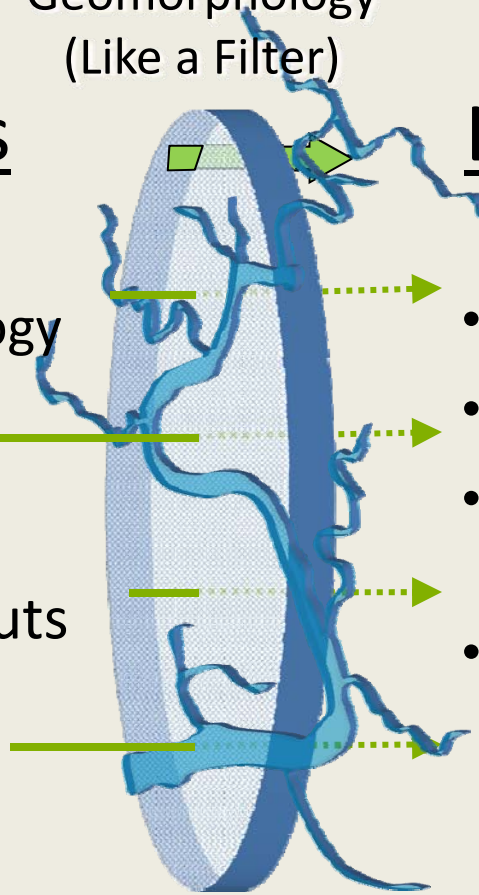

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First Mallard Branch

Structure influences function

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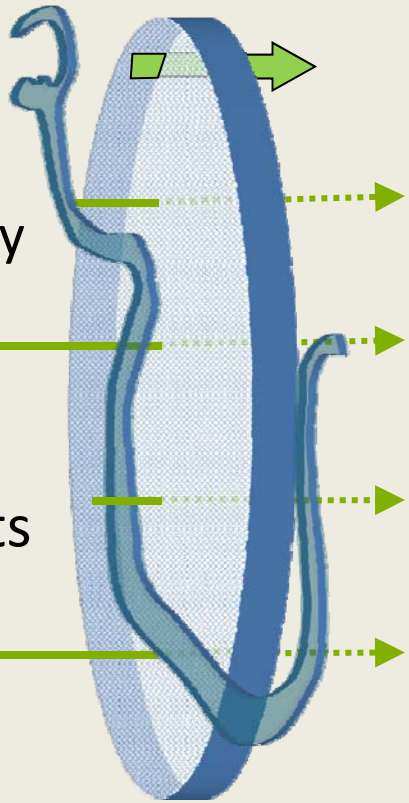

Sheldrake Slough

Drivers
(forcing)

- Meteorology
- Tides
- River inputs

Linkages
(processes)

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- Dispersion
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Outcomes
(Chemical/Biological Habitat Characteristics)

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- **Temperature**
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- etc.

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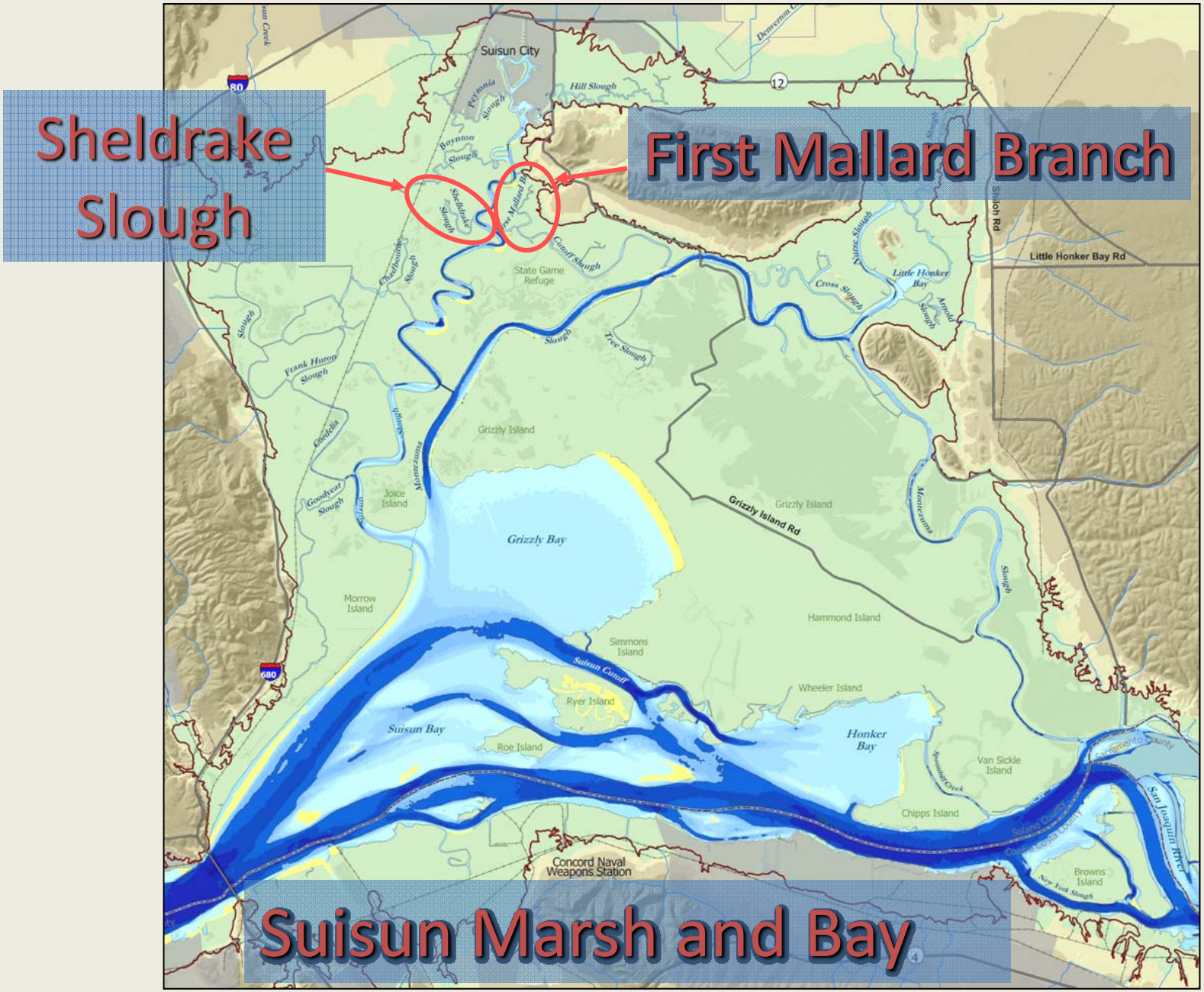

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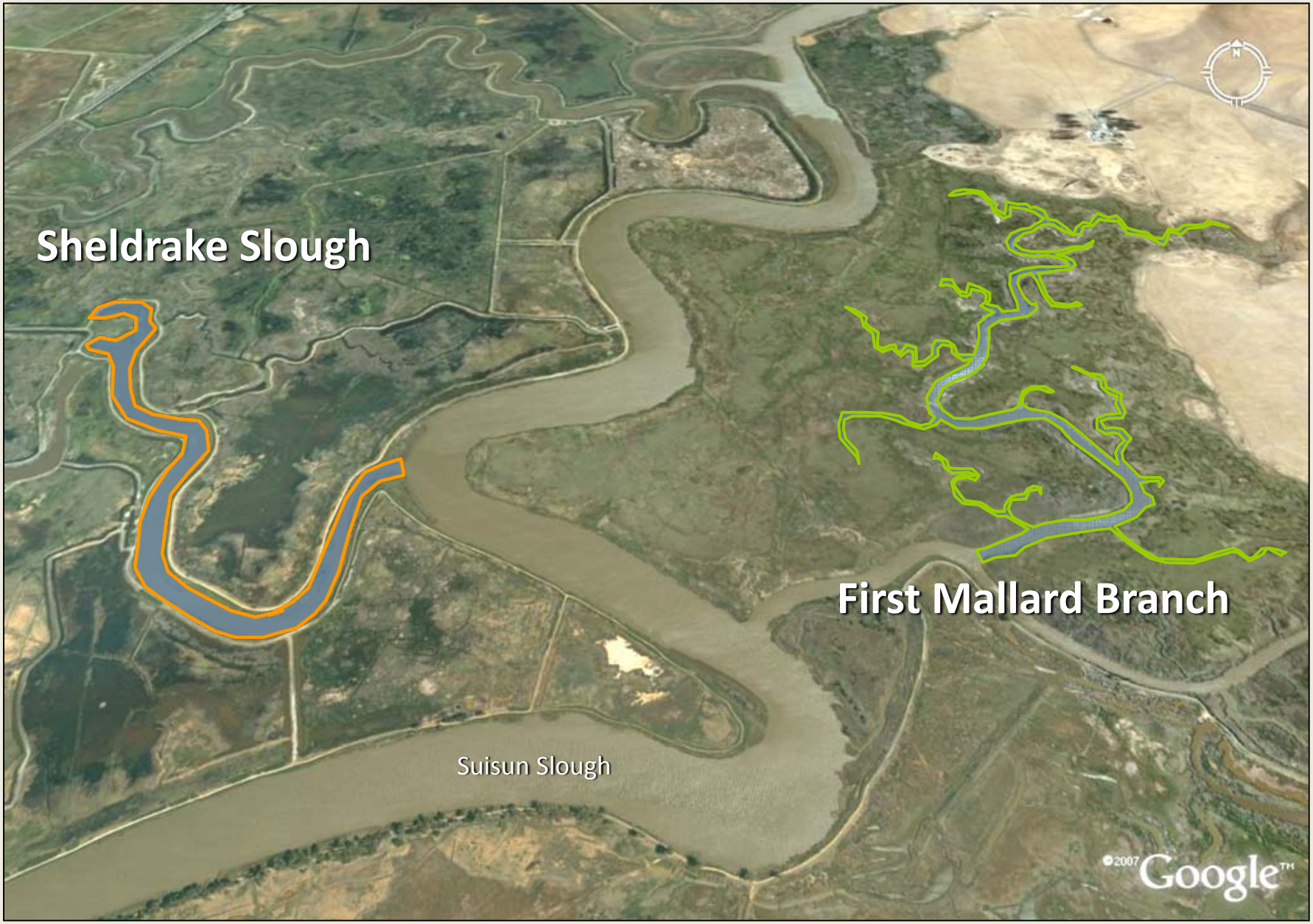

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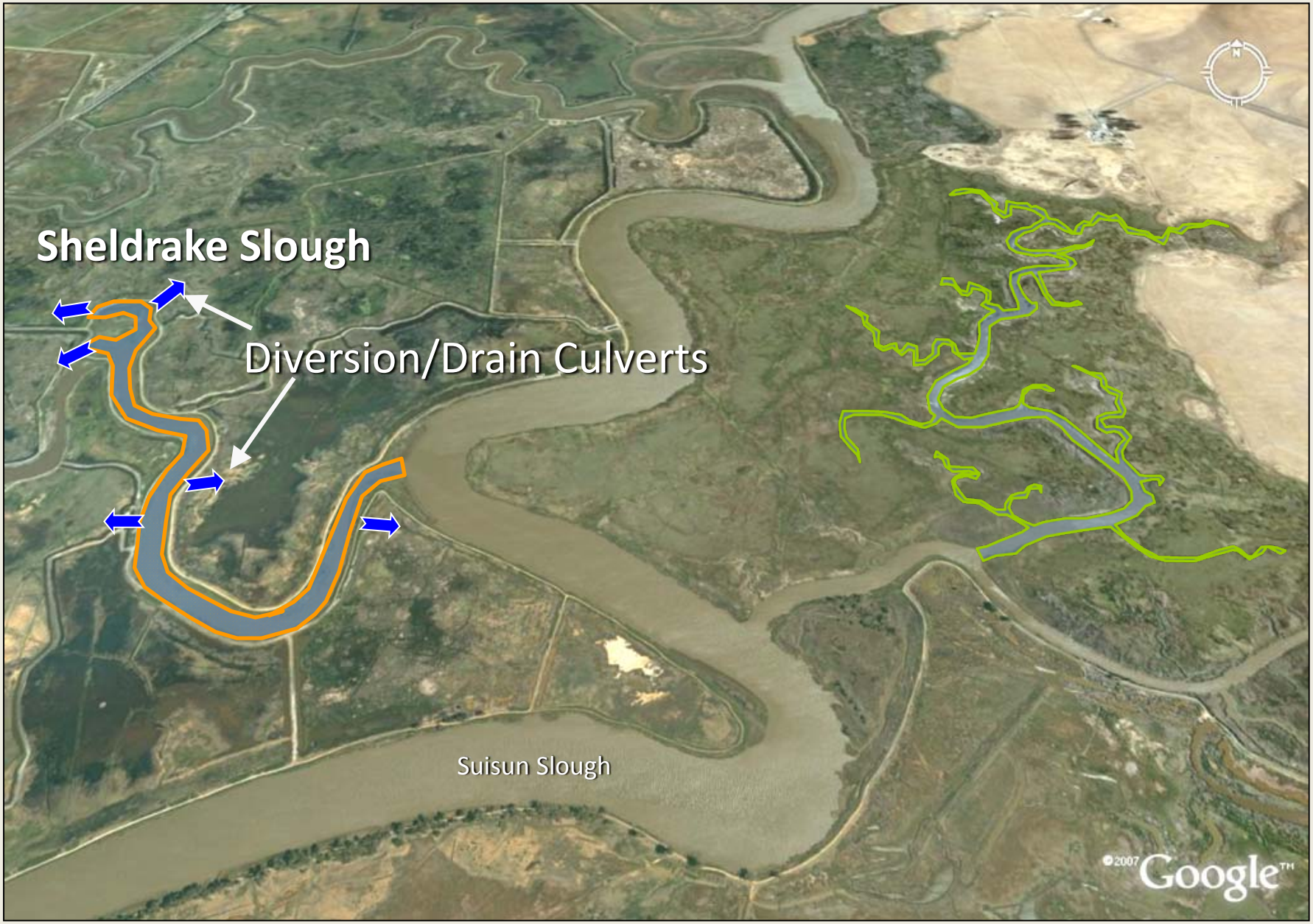

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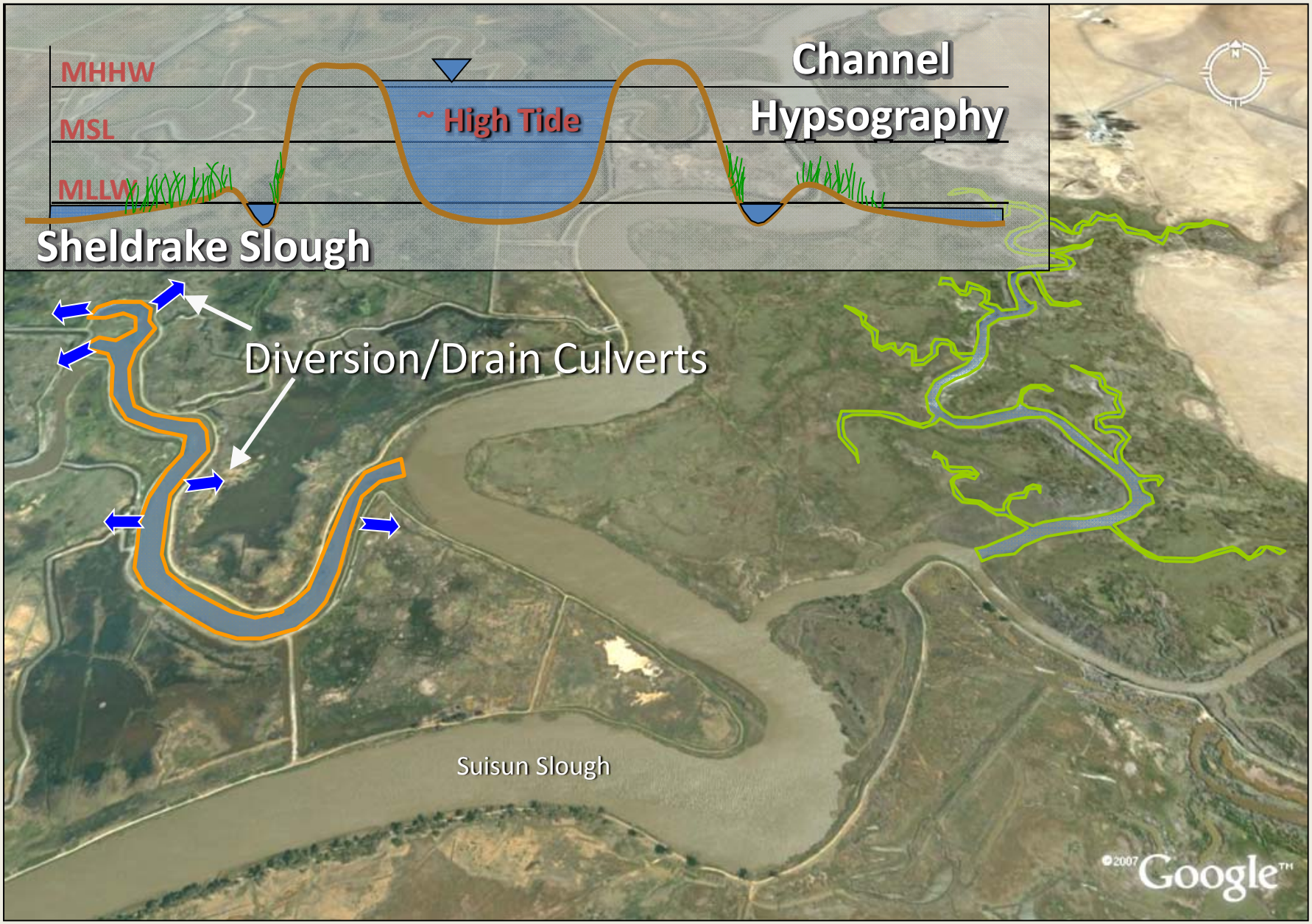

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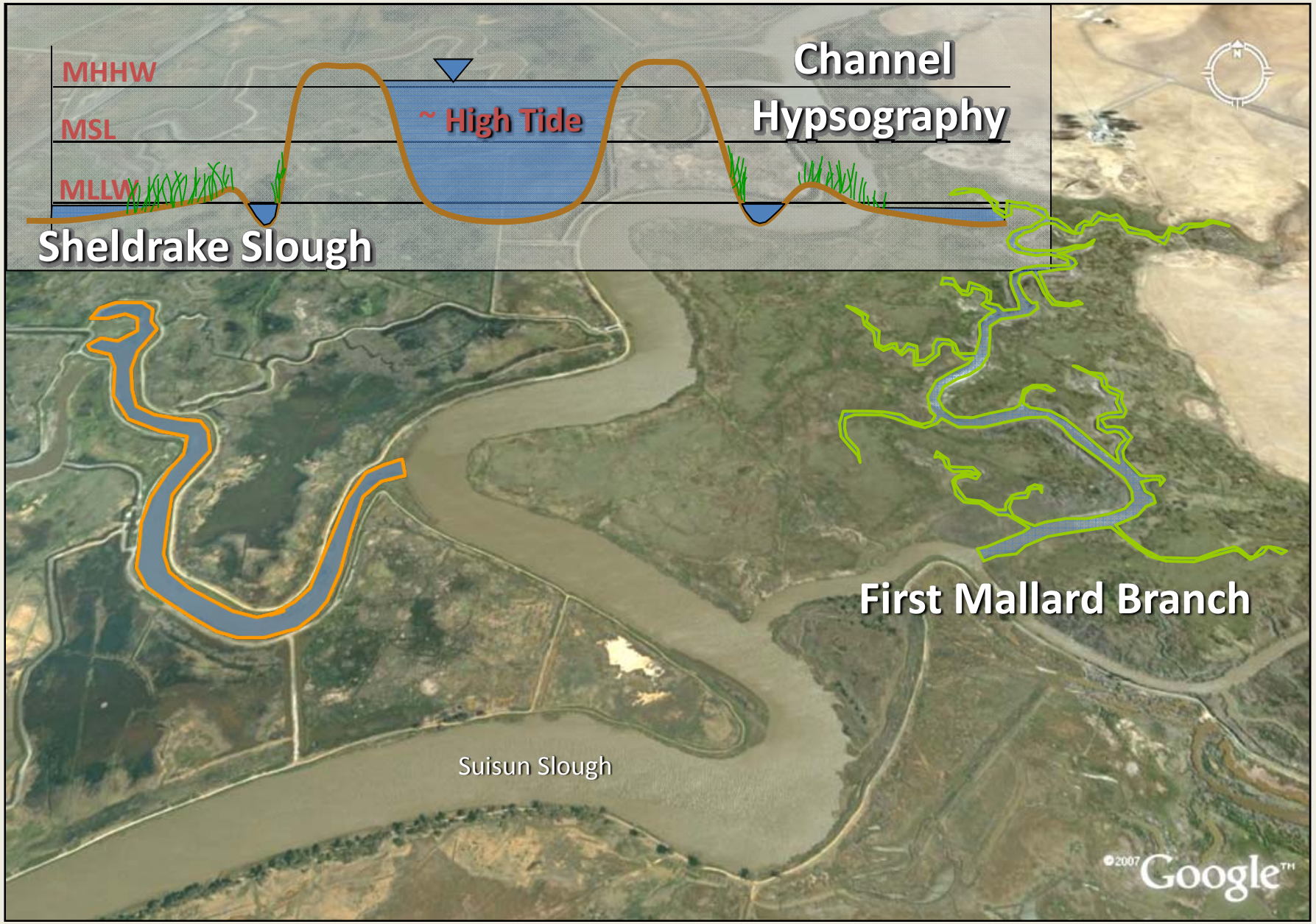

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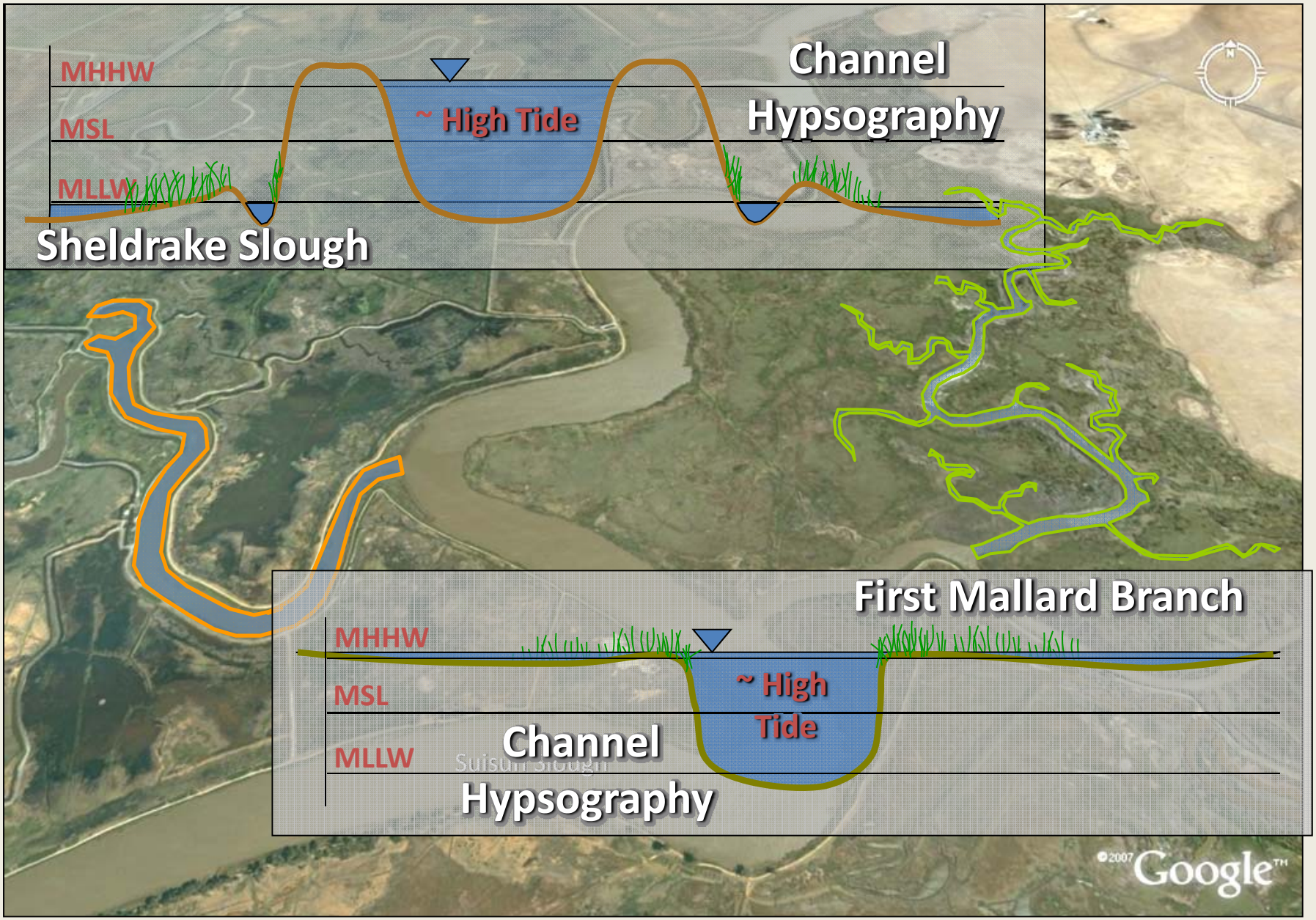

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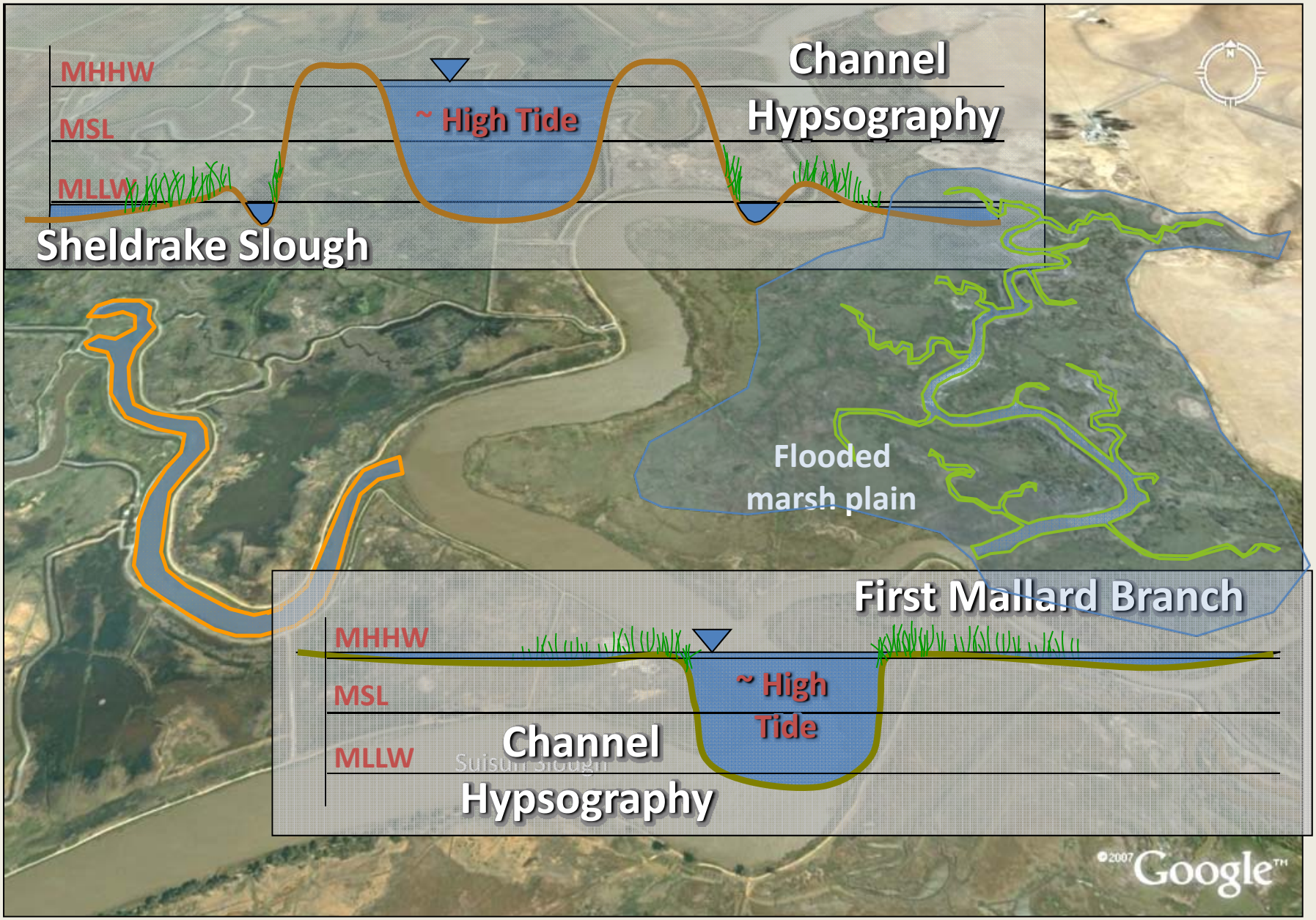

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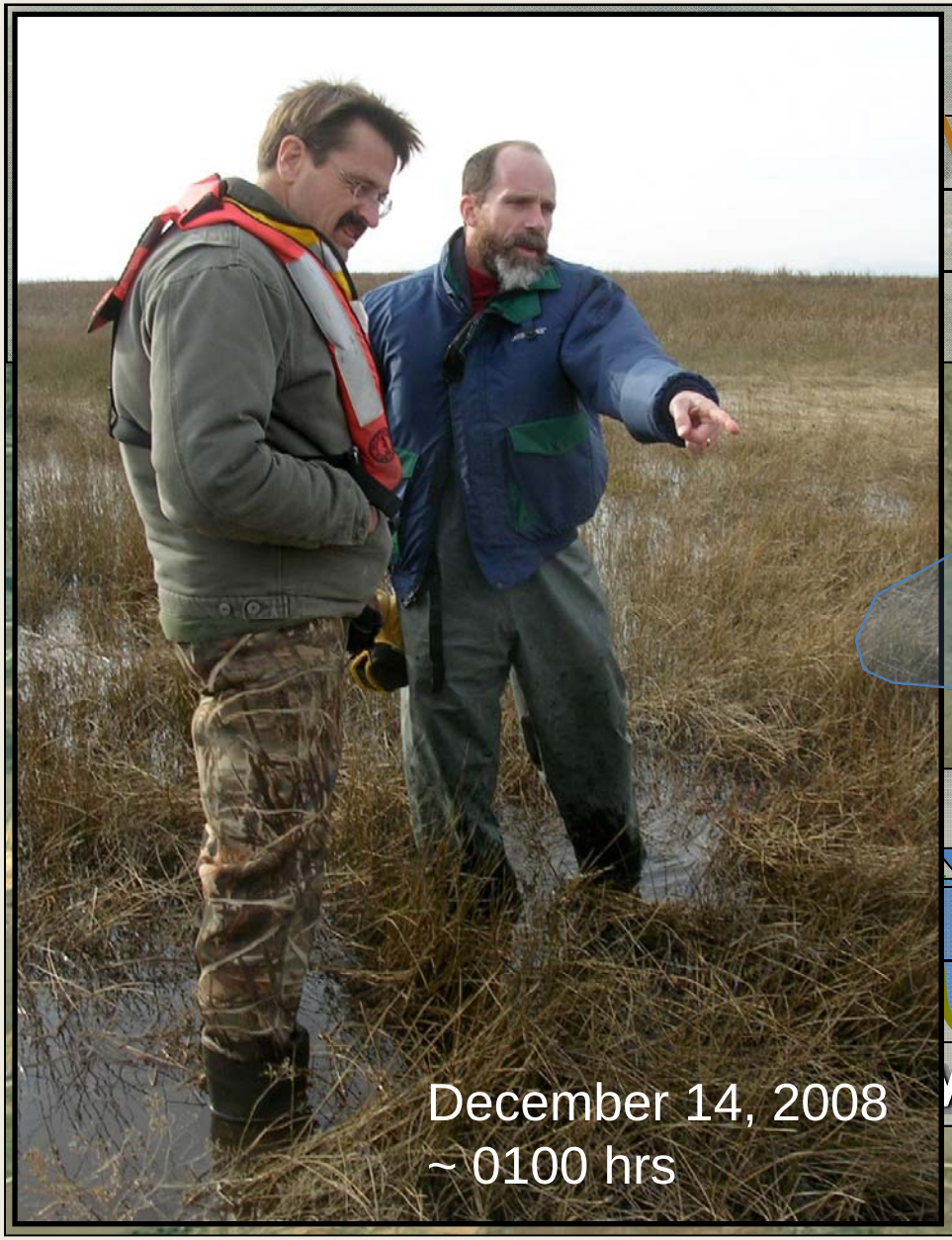

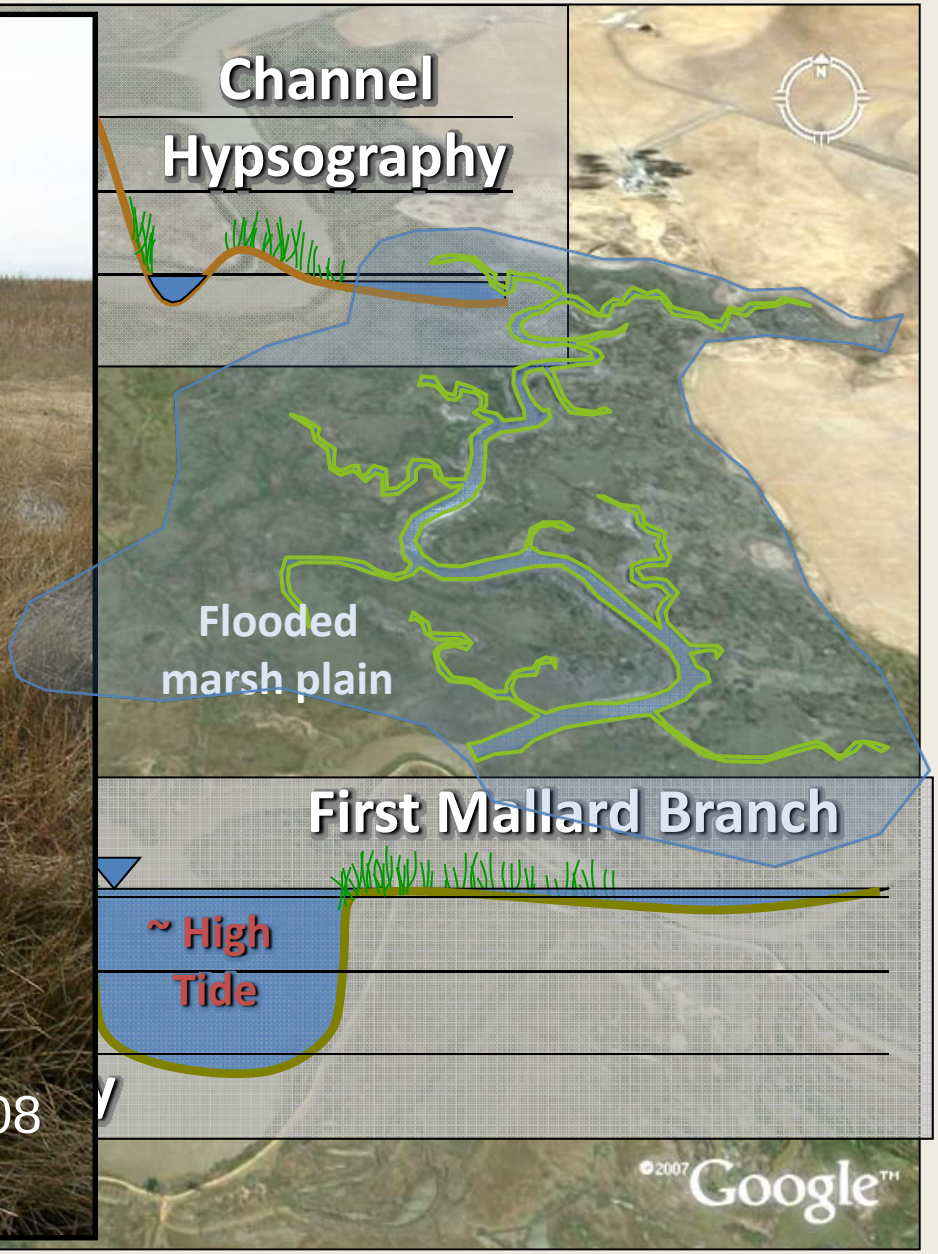

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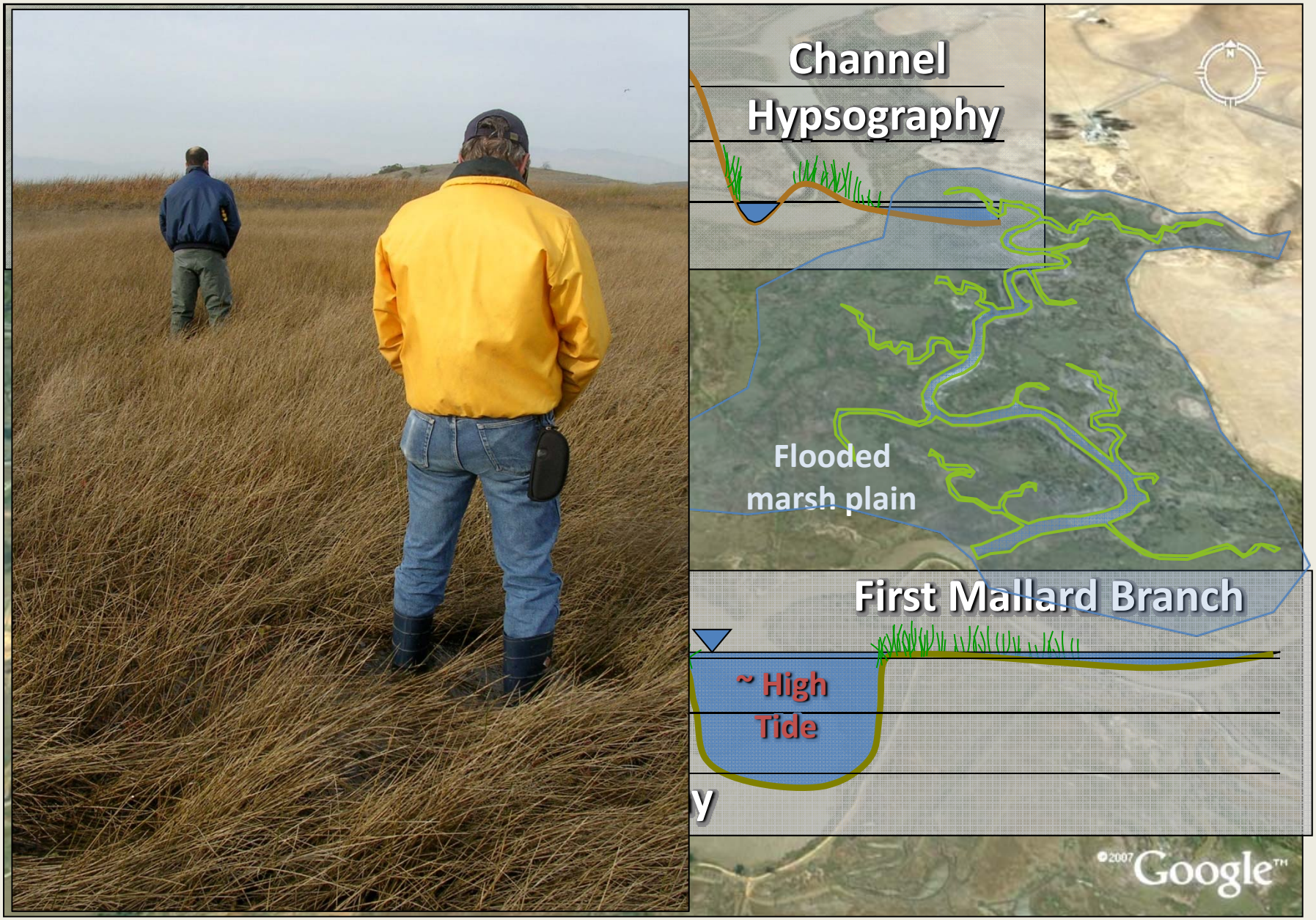

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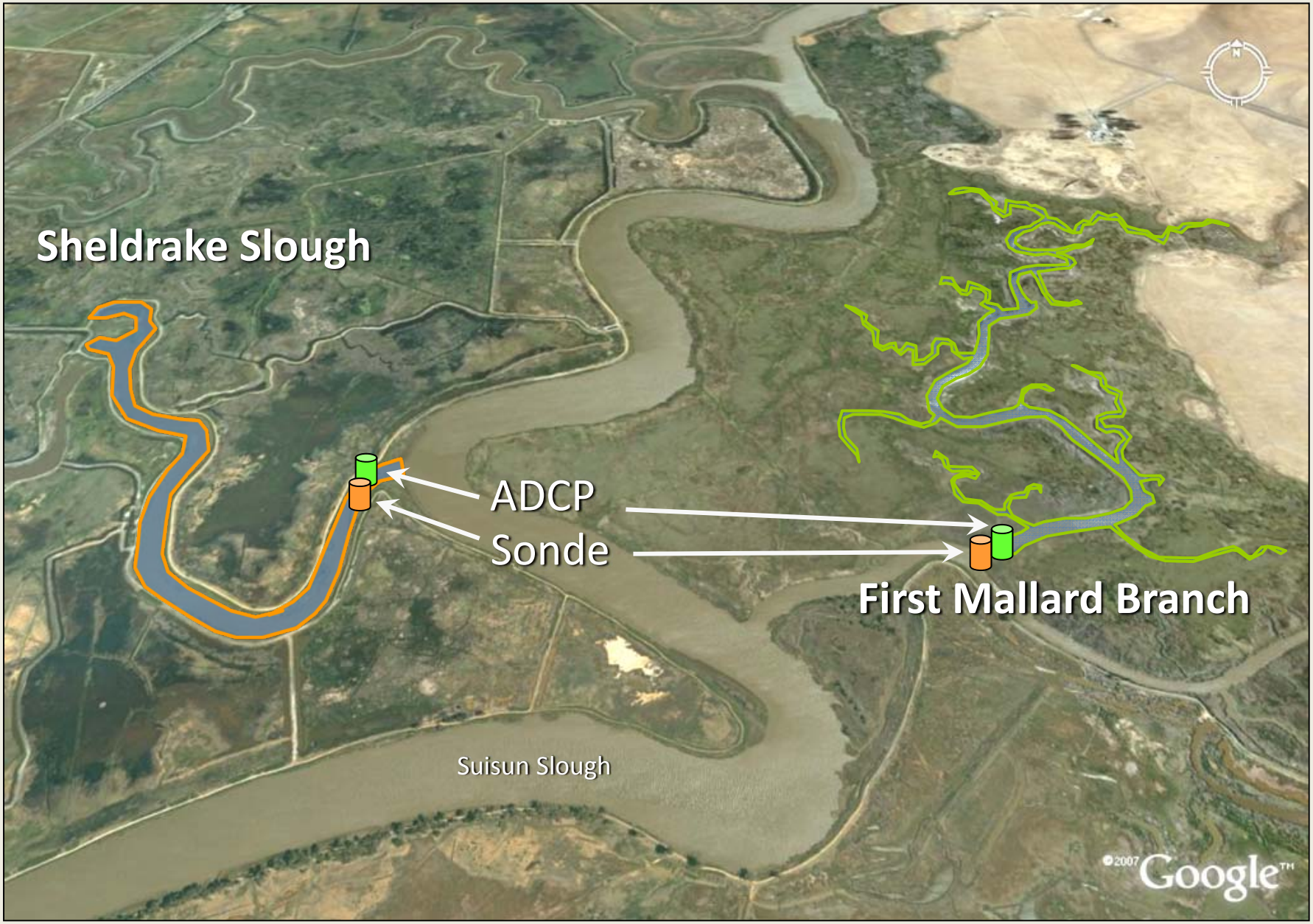
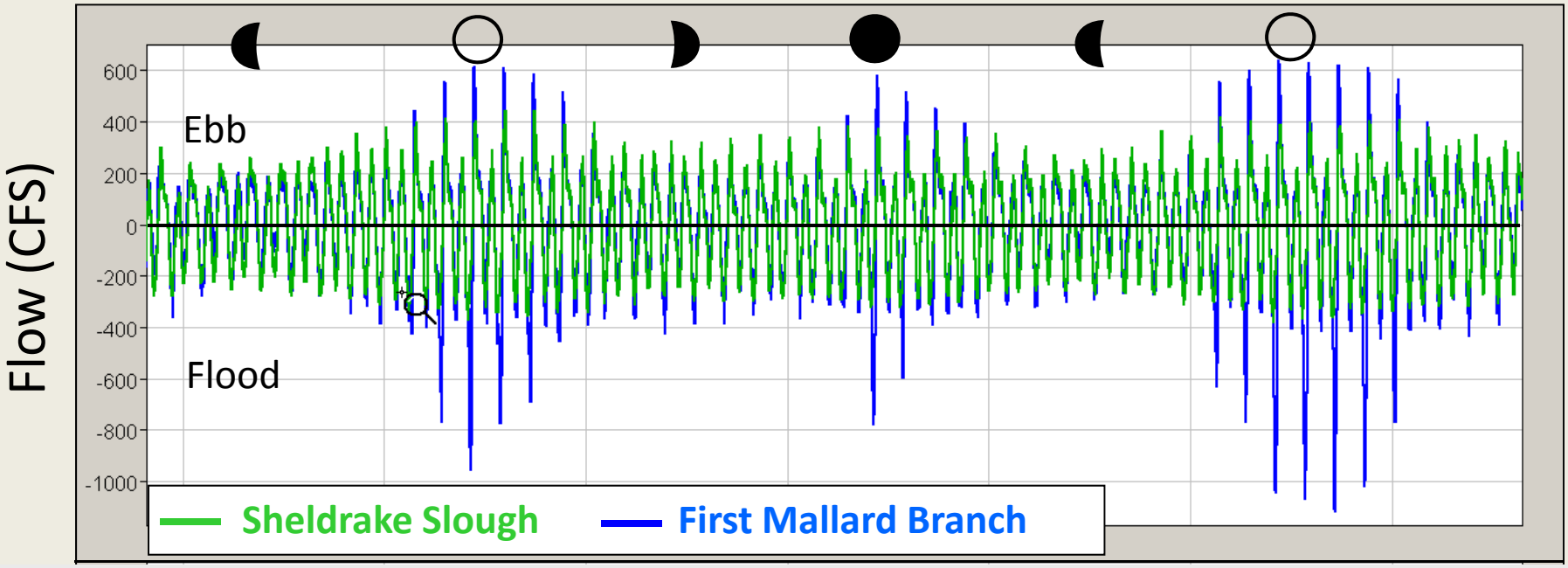


3c. Temperature as f(structure)

Tidal Flow



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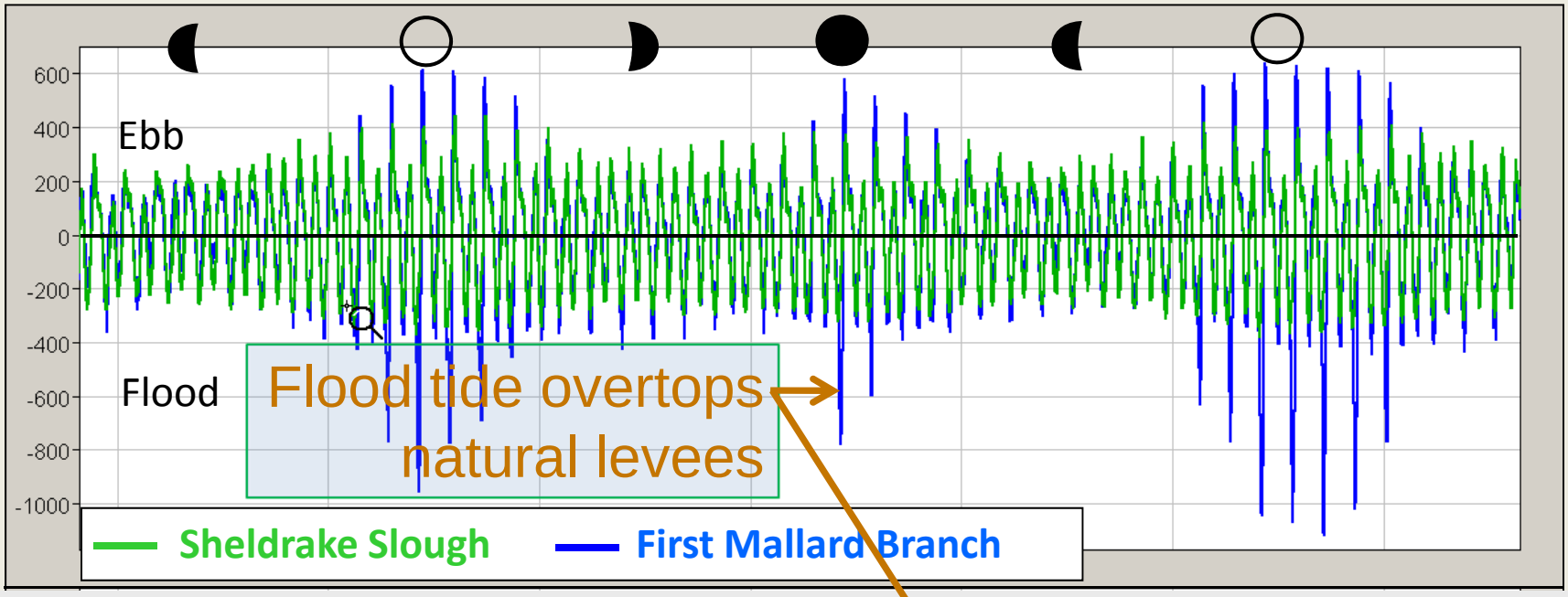
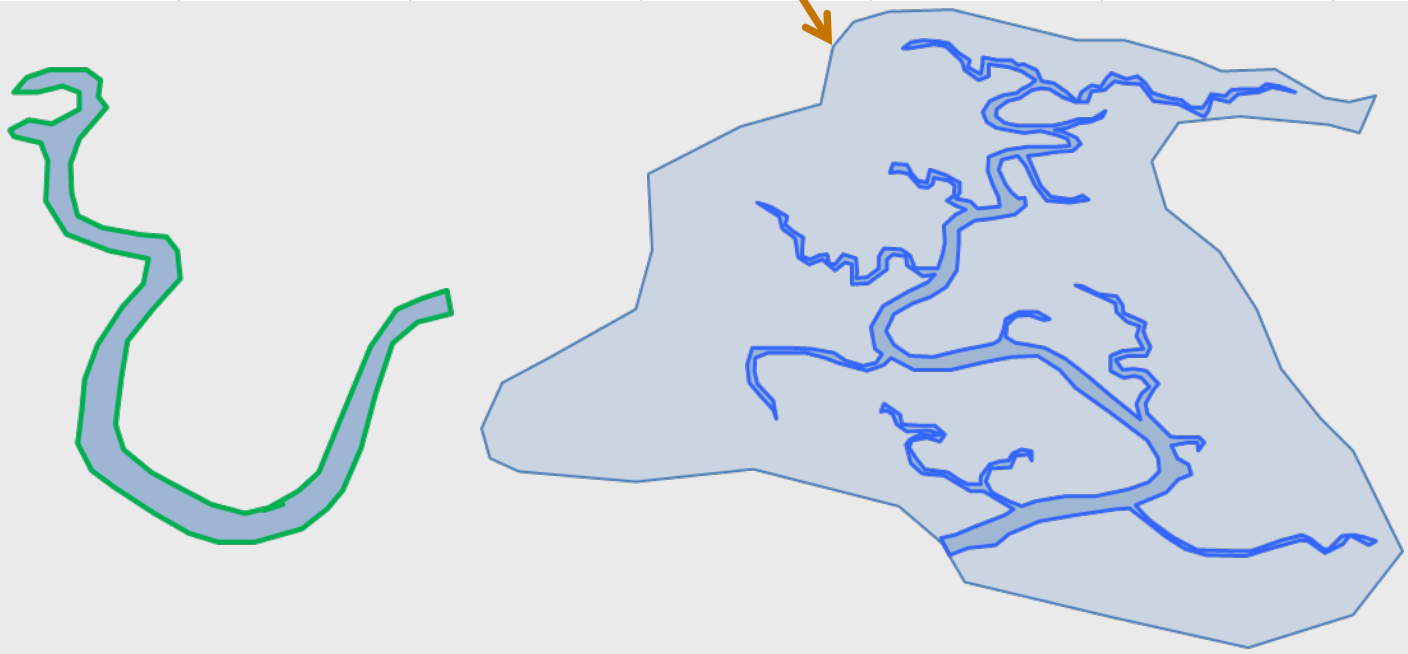
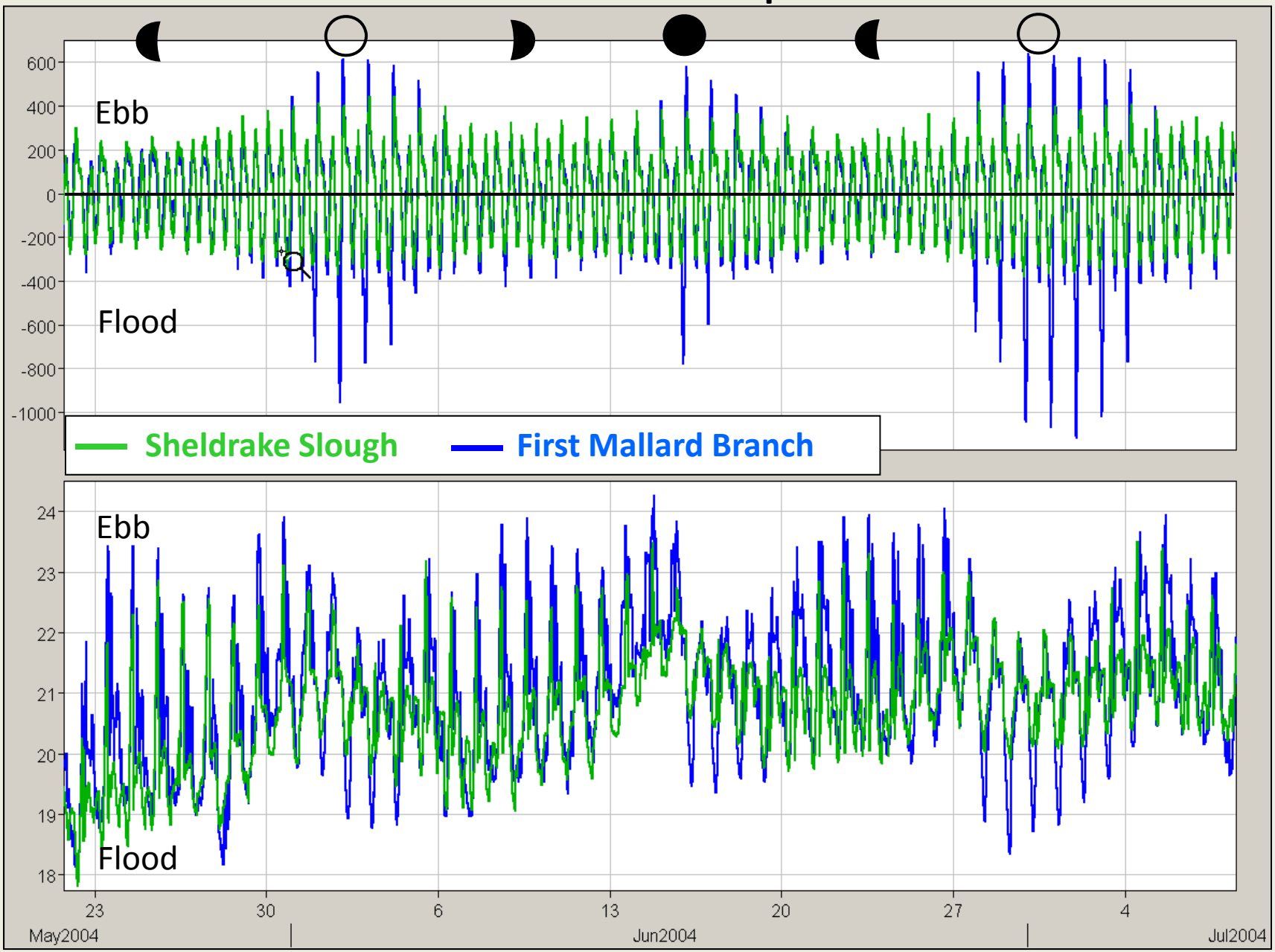




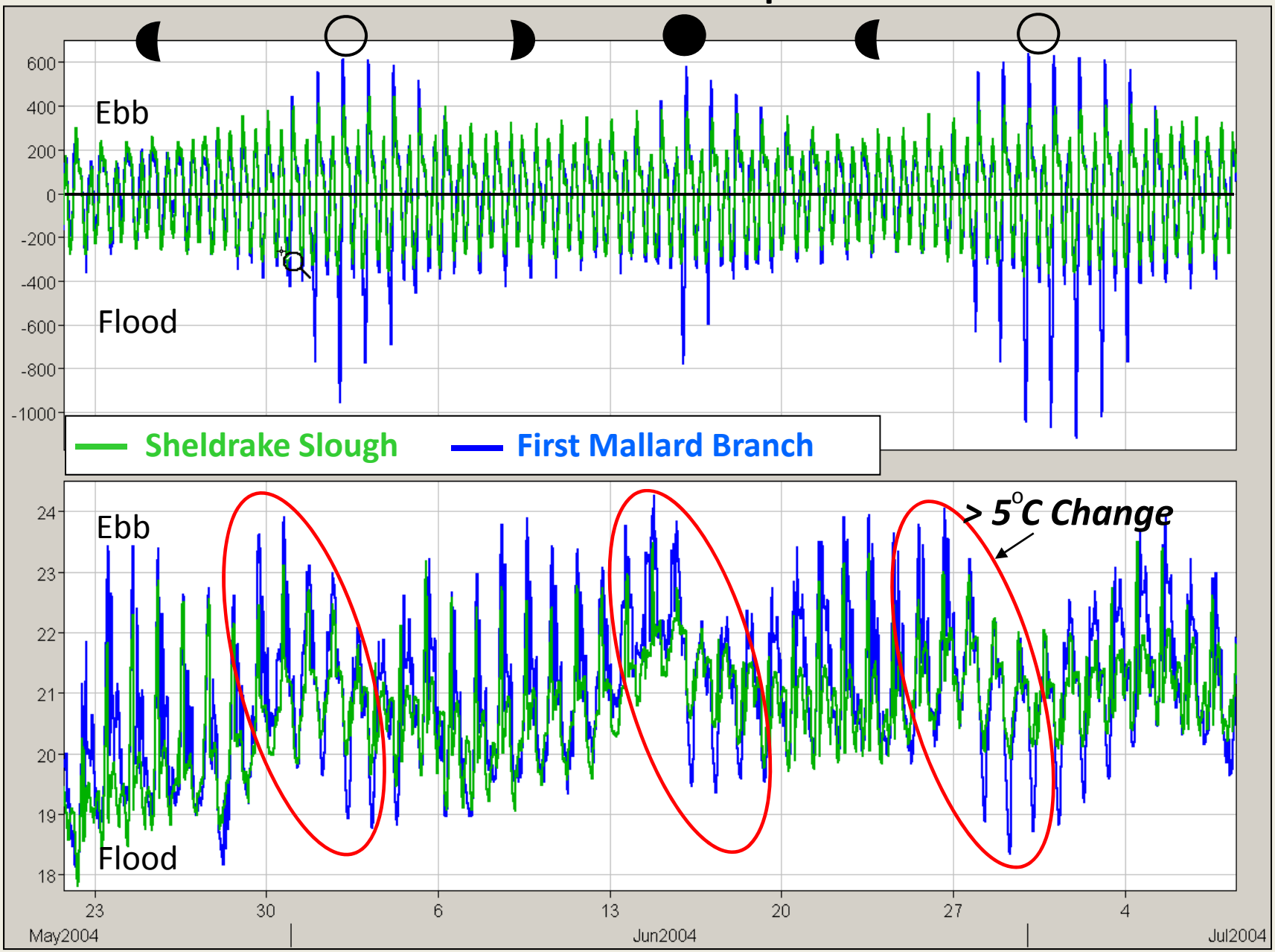
3c. Temperature as f(structure)

Tidal Flow and Temperature



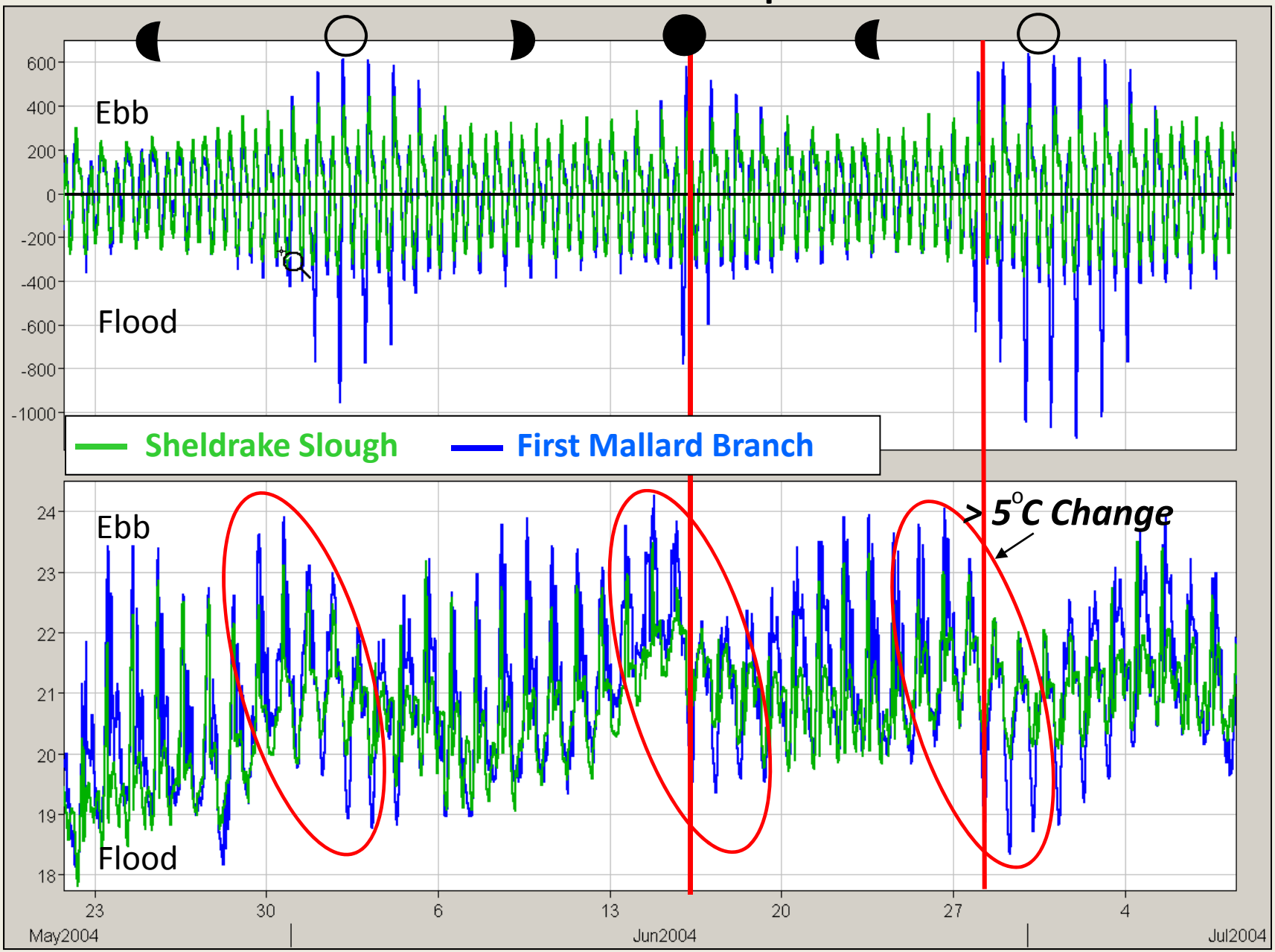
3c. Temperature as f(structure)

Tidal Flow and Temperature



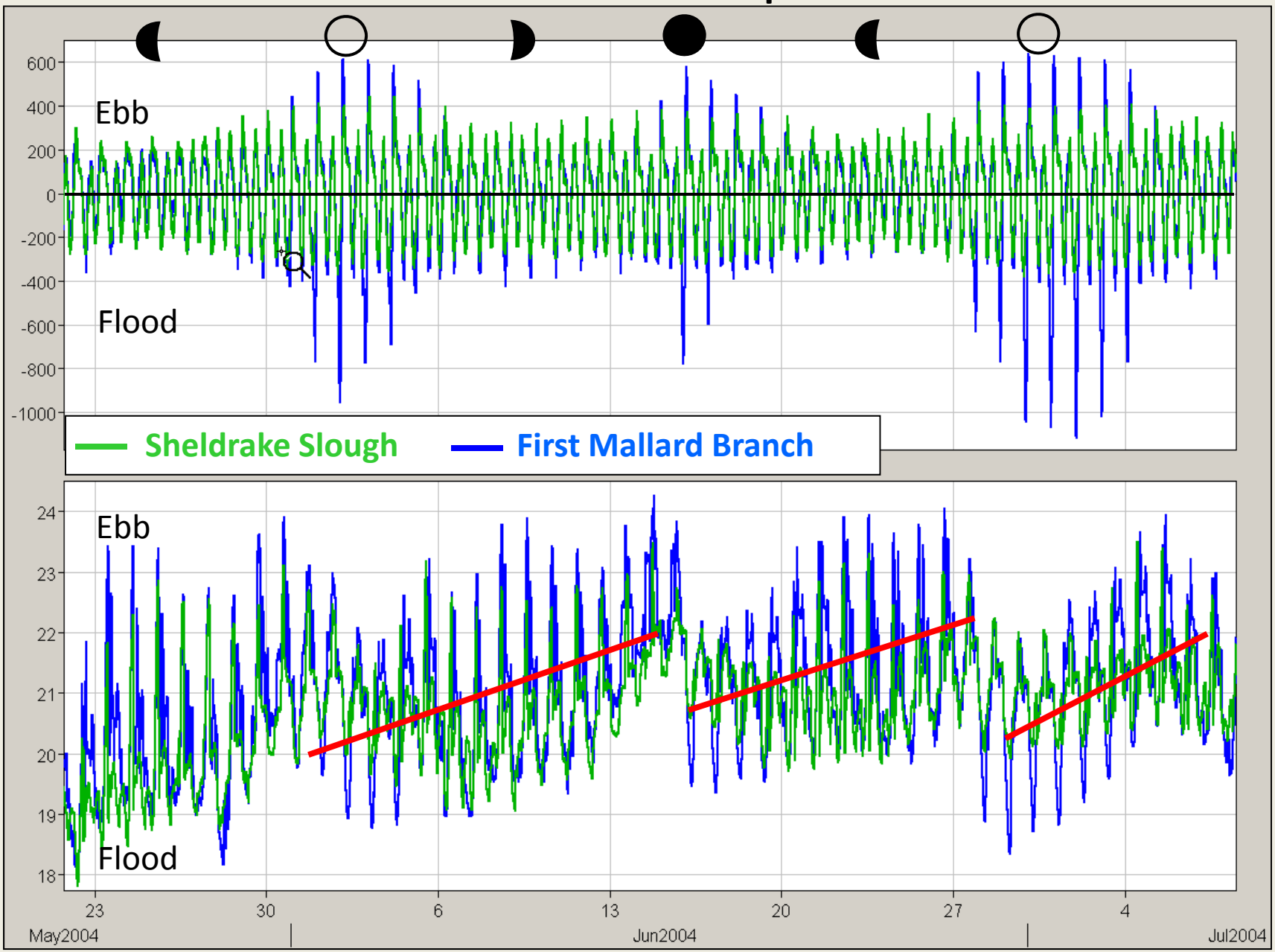
3c. Temperature as f(structure)

Tidal Flow and Temperature



3c. Temperature as f(structure)

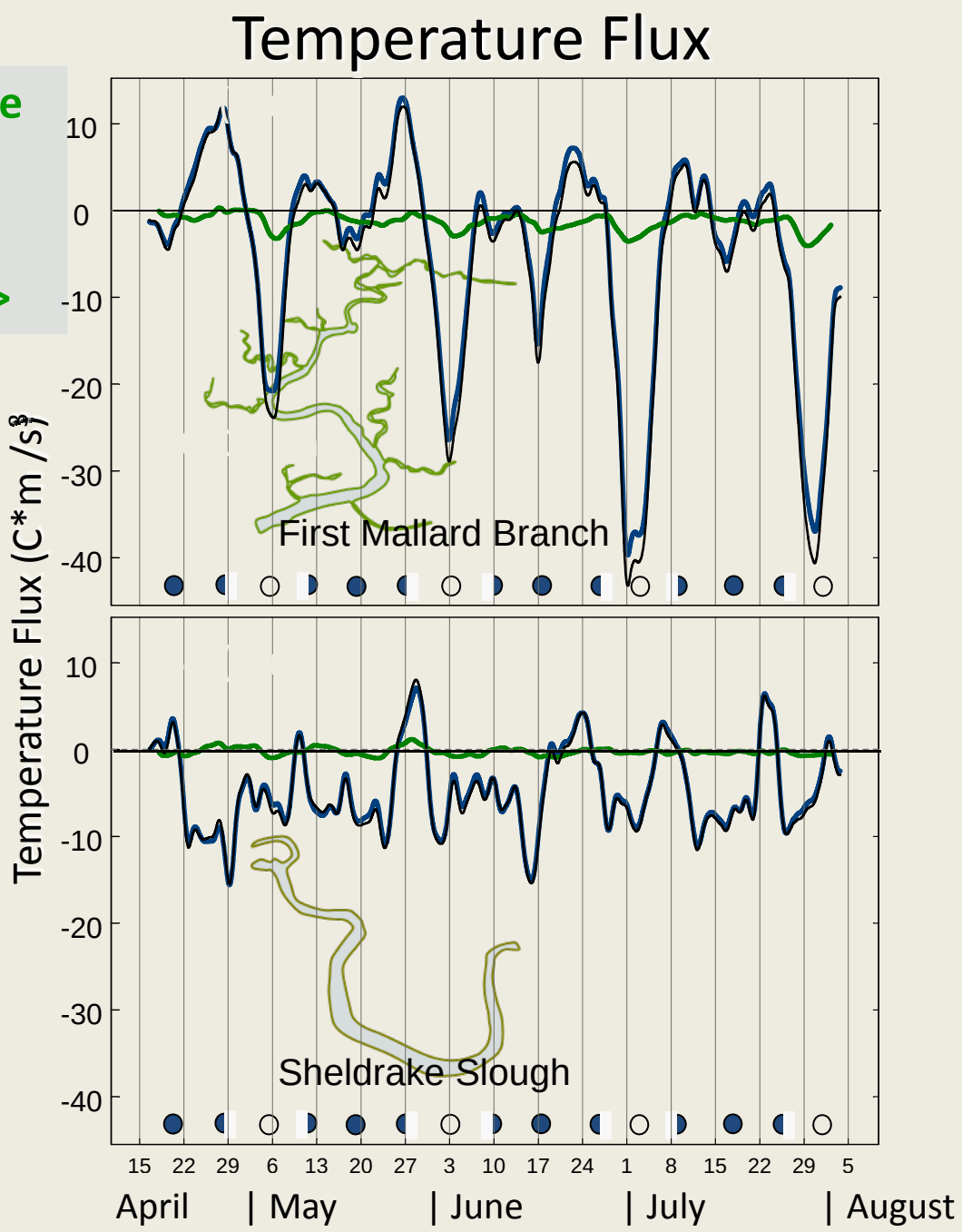
Tidal Flow and Temperature



3c. Temperature as f(structure)

Total Flux = **Advective Flux** (Spring Neap) + **Dispersive Flux** (Tides)

$\langle Qt*Ct \rangle = \langle Qt \rangle \langle Ct \rangle + \langle Q't*C't \rangle$



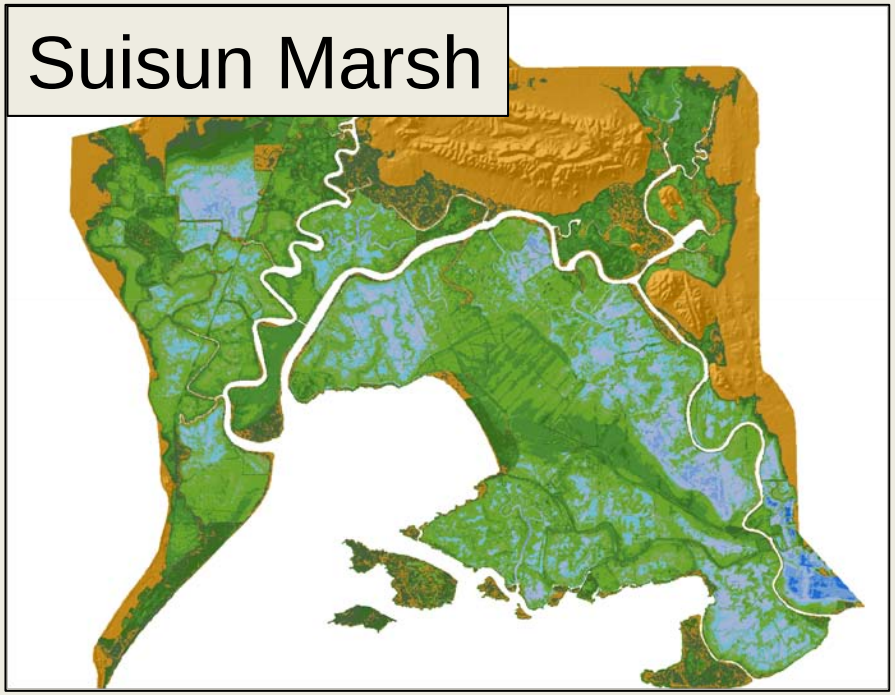
4. Implications for restoration

- Historical landscape to Modern restoration– it's a big leap…
- Trajectories of change will be decadal.
- We'll need designs that do it all:
  - Restore dendritic tidal marsh hydrogeomorphology.
  - Keep pace with sea level rise.
  - Support listed species needs now.
  - Don't make it worse!
  - Are adaptable

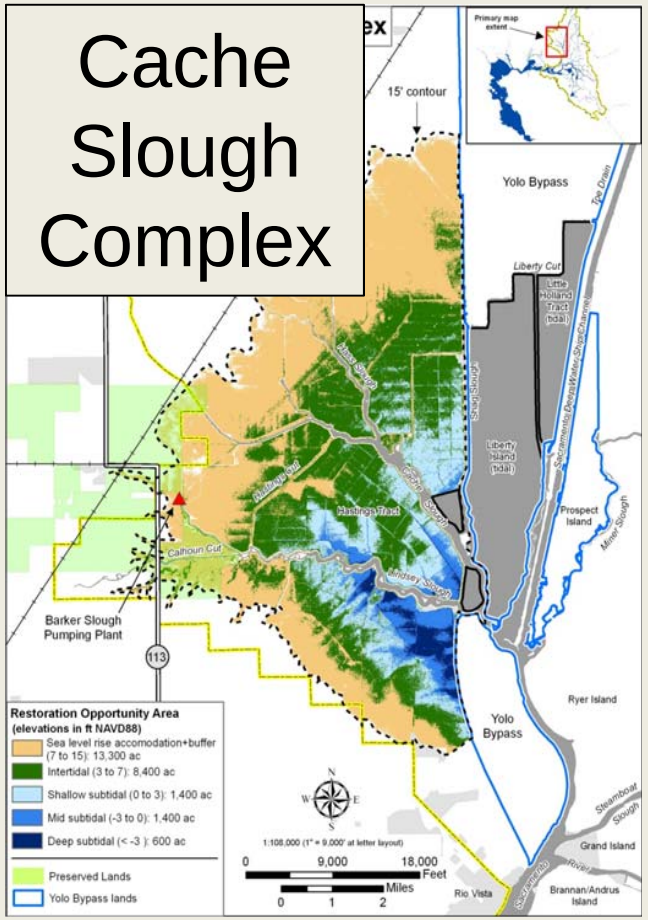
4. Implications for restoration

The initial condition is elevation challenged

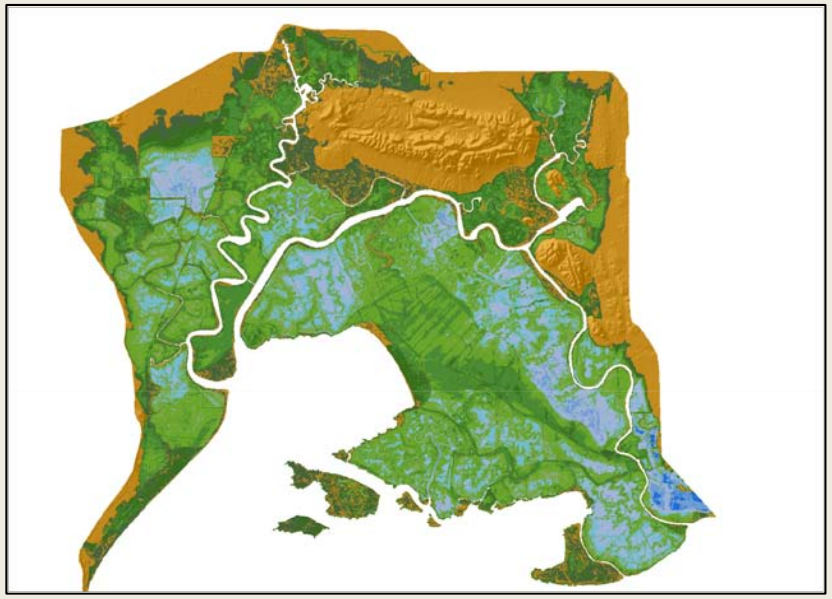
Suisun Marsh

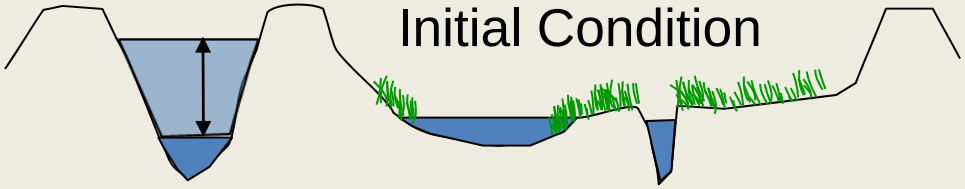


Cache Slough Complex

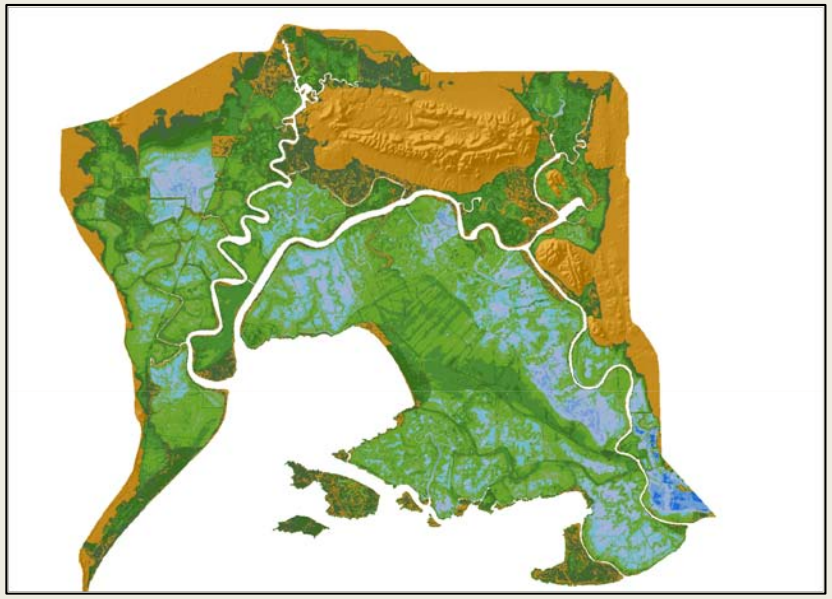


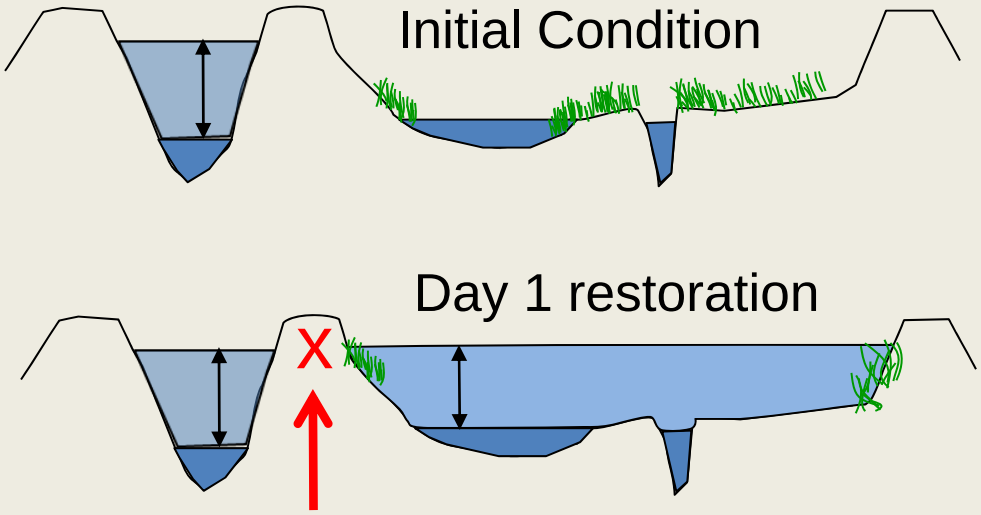
4. Implications for restoration





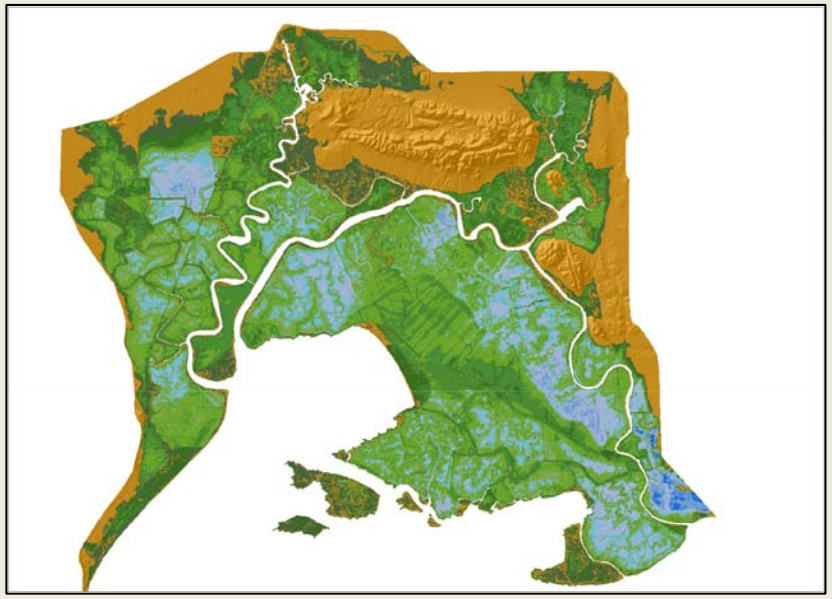
4. Implications for restoration

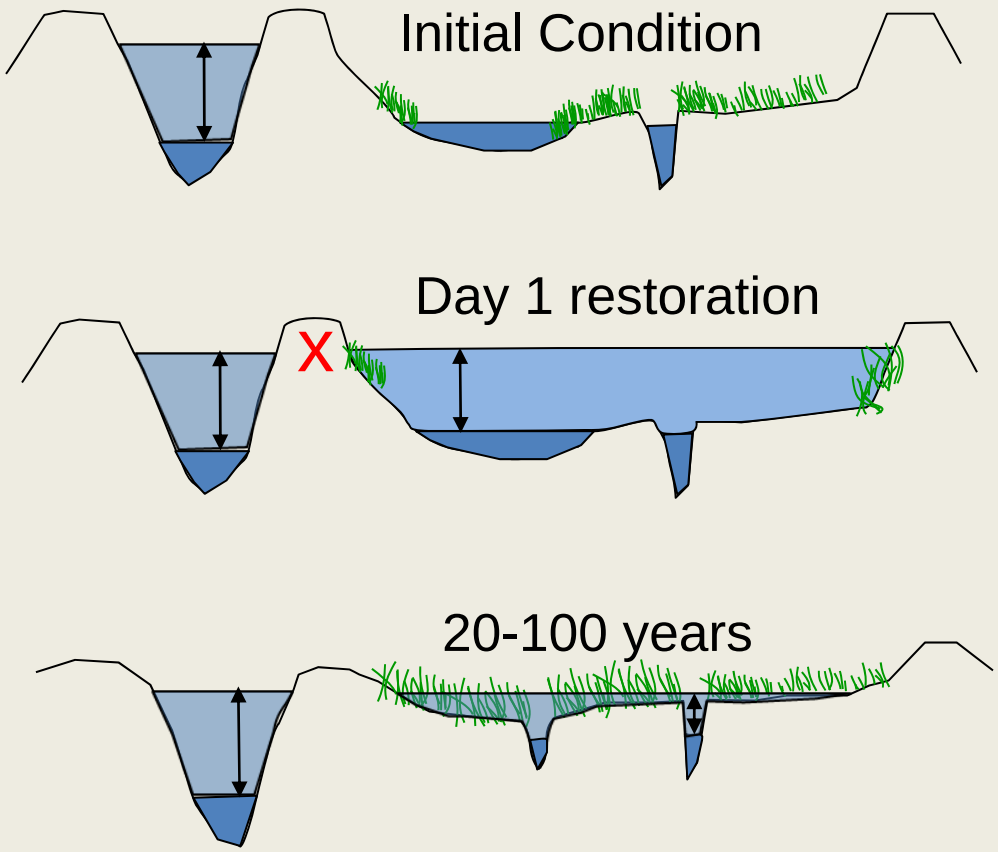




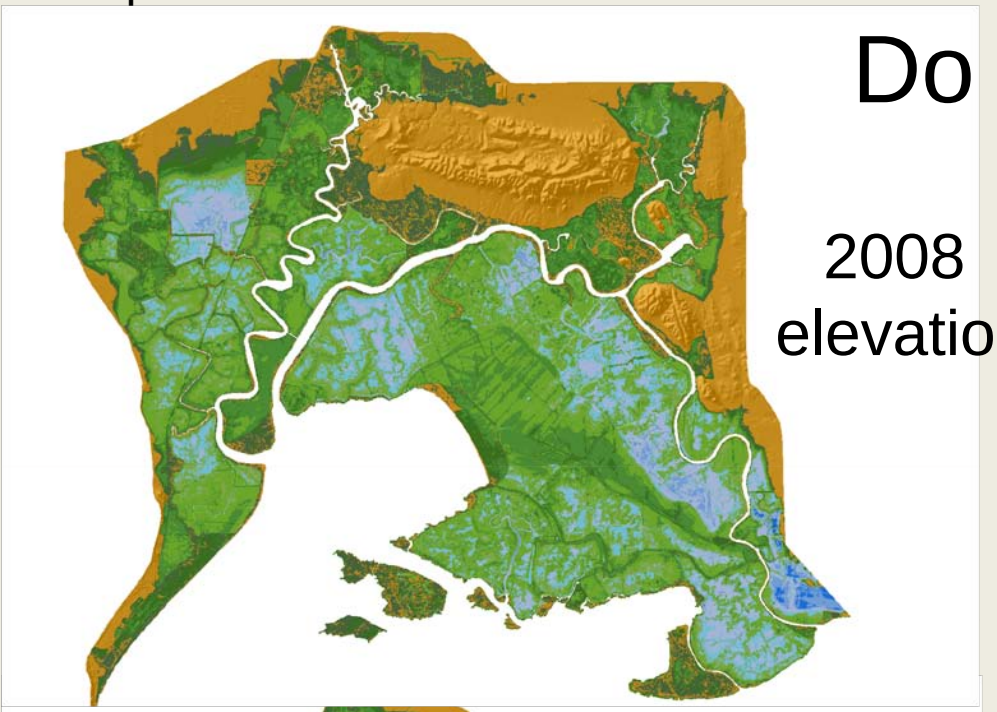
The levee breach “knob”:
where, how many,
how wide, how deep

4. Implications for restoration

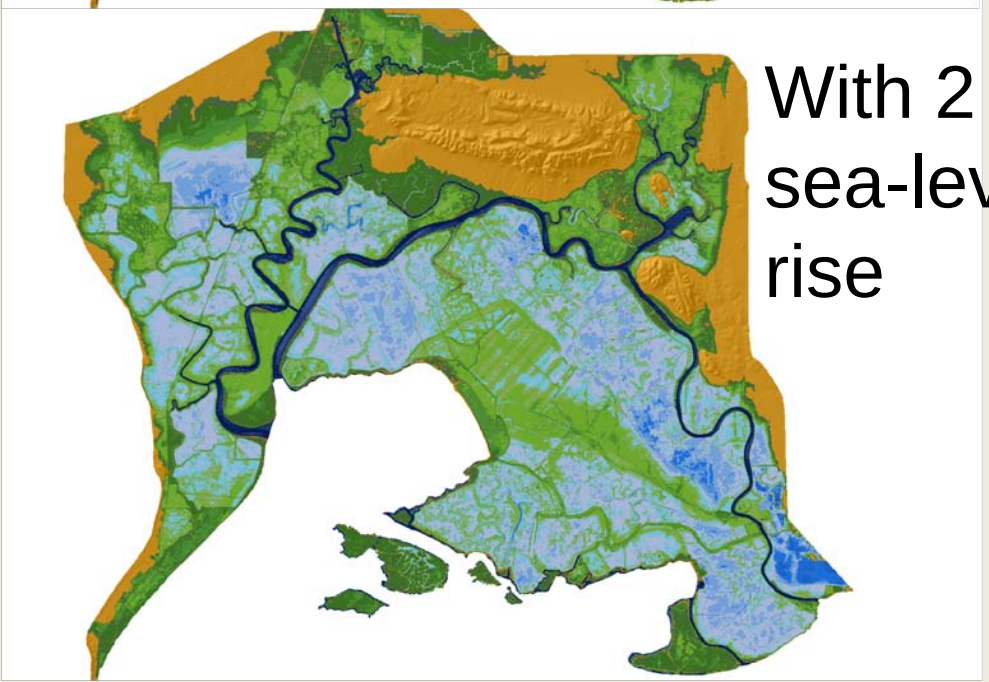




Do nothing scenario



2008 elevation



With 2 foot sea-level rise

Elevation (ft)

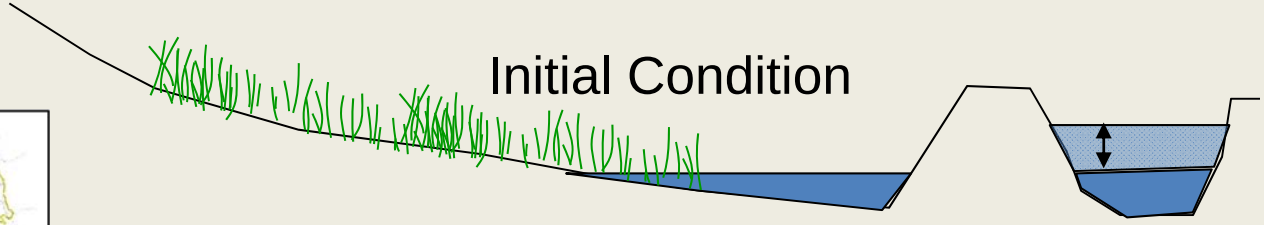
Subtidal elevation

- <-16.4
- -16.4 - -9.8
- -9.7 - -8.2
- -8.1 - -6.6
- -6.5 - -4.9
- -4.8 - -3.3
- -3.2 - -1.6
- -1.5 - 0
- 0.01 - 0.9

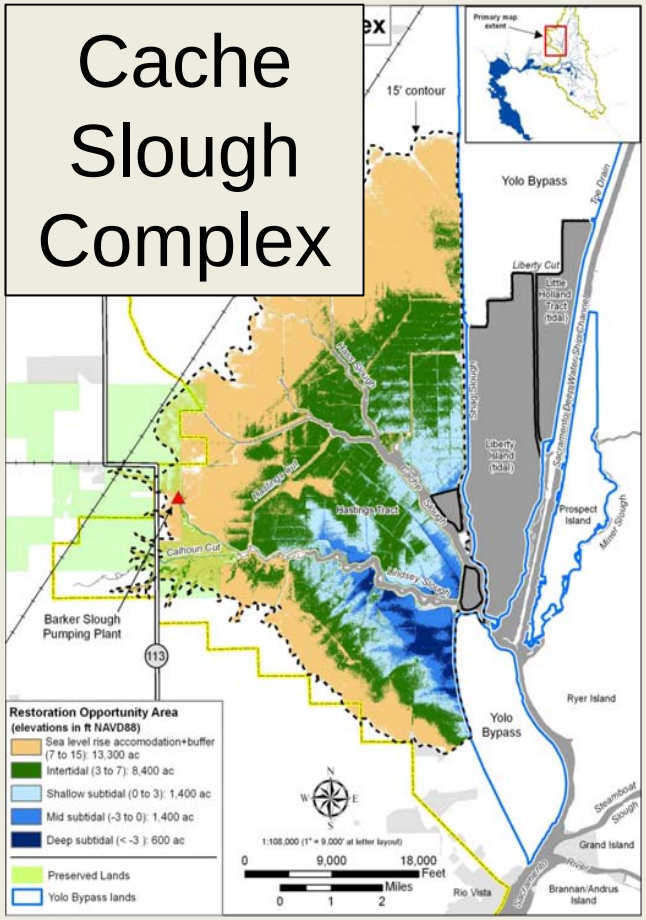
Intertidal elevation

- 1.0 - 1.6
- 1.7 - 3.3
- 3.4 - 4.9
- 5.0 - 6.4
- 6.5 - 8.2
- >8.2

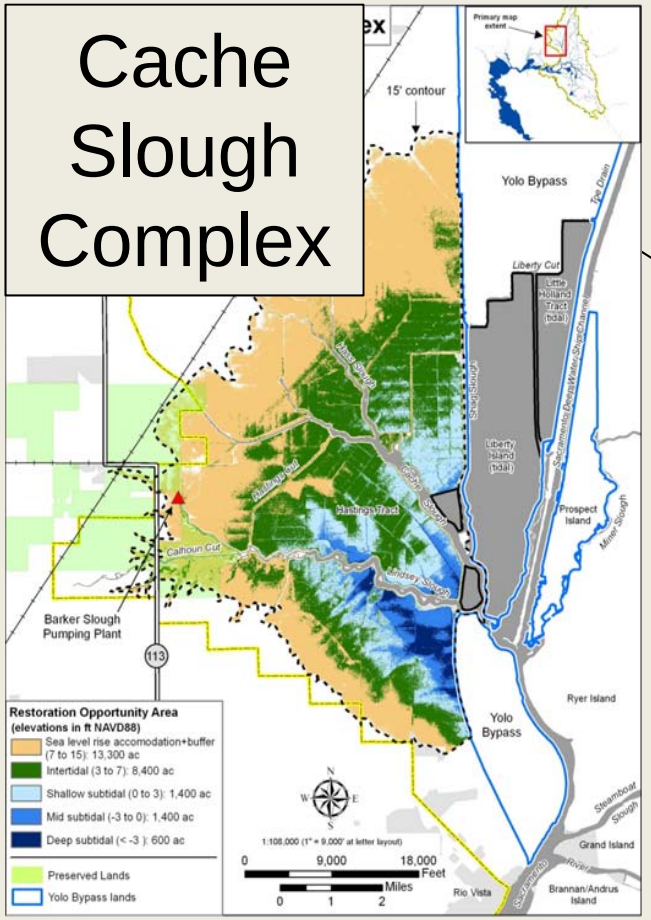
4. Implications for restoration

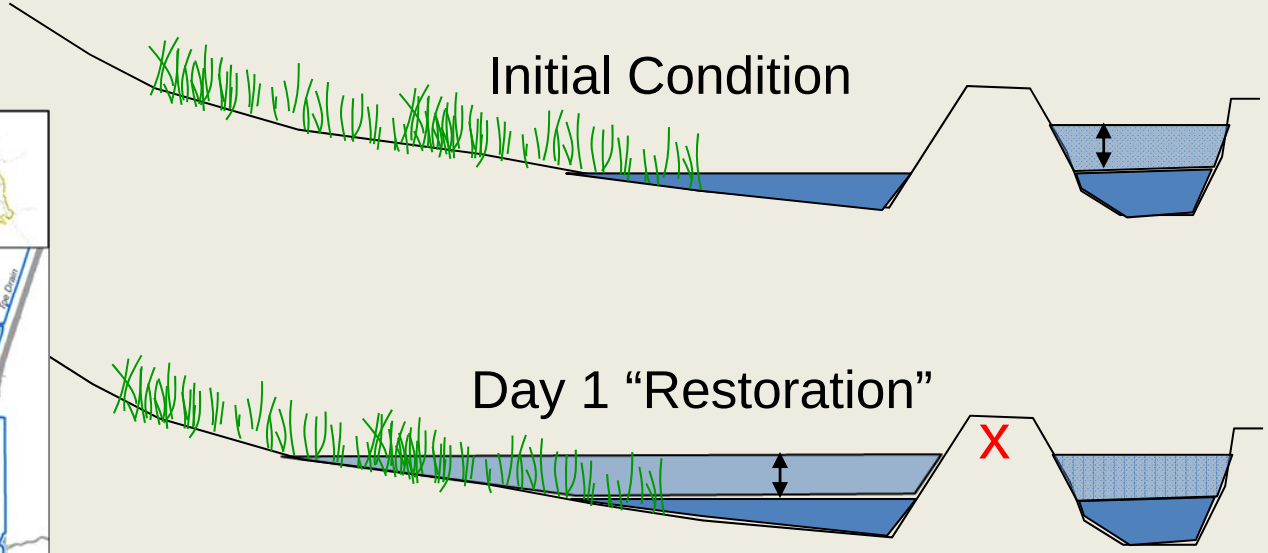


Cache Slough Complex

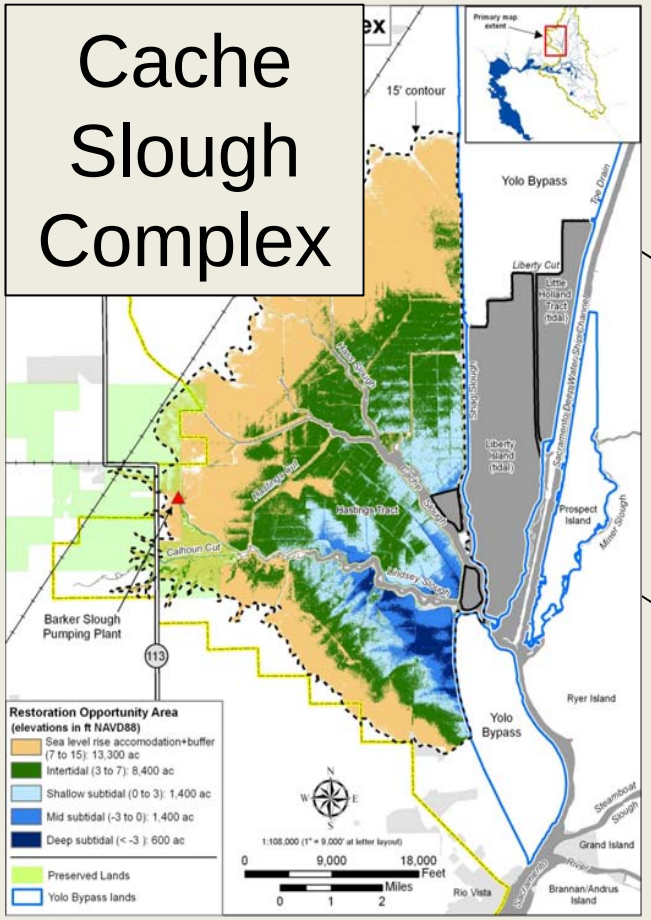


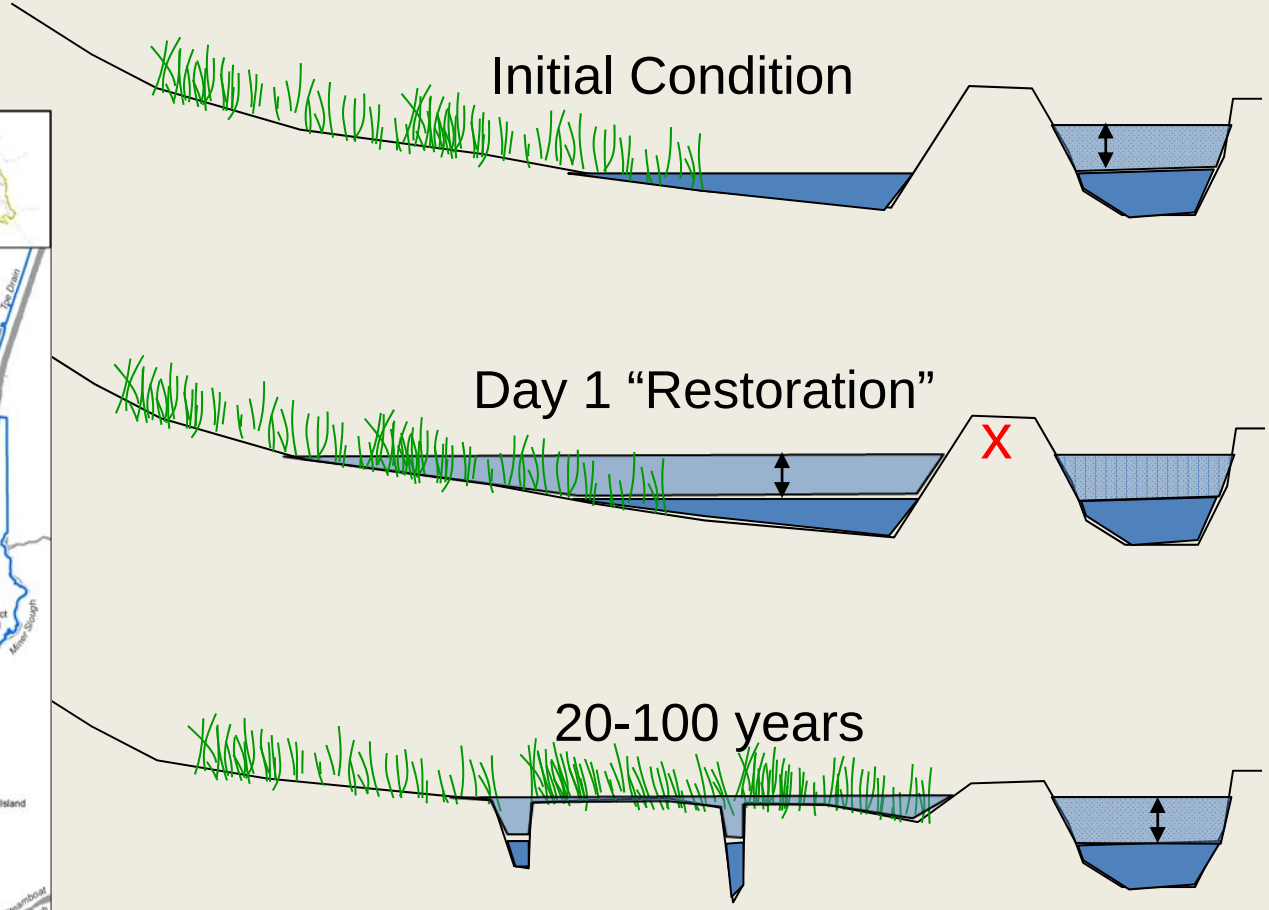
4. Implications for restoration





4. Implications for restoration





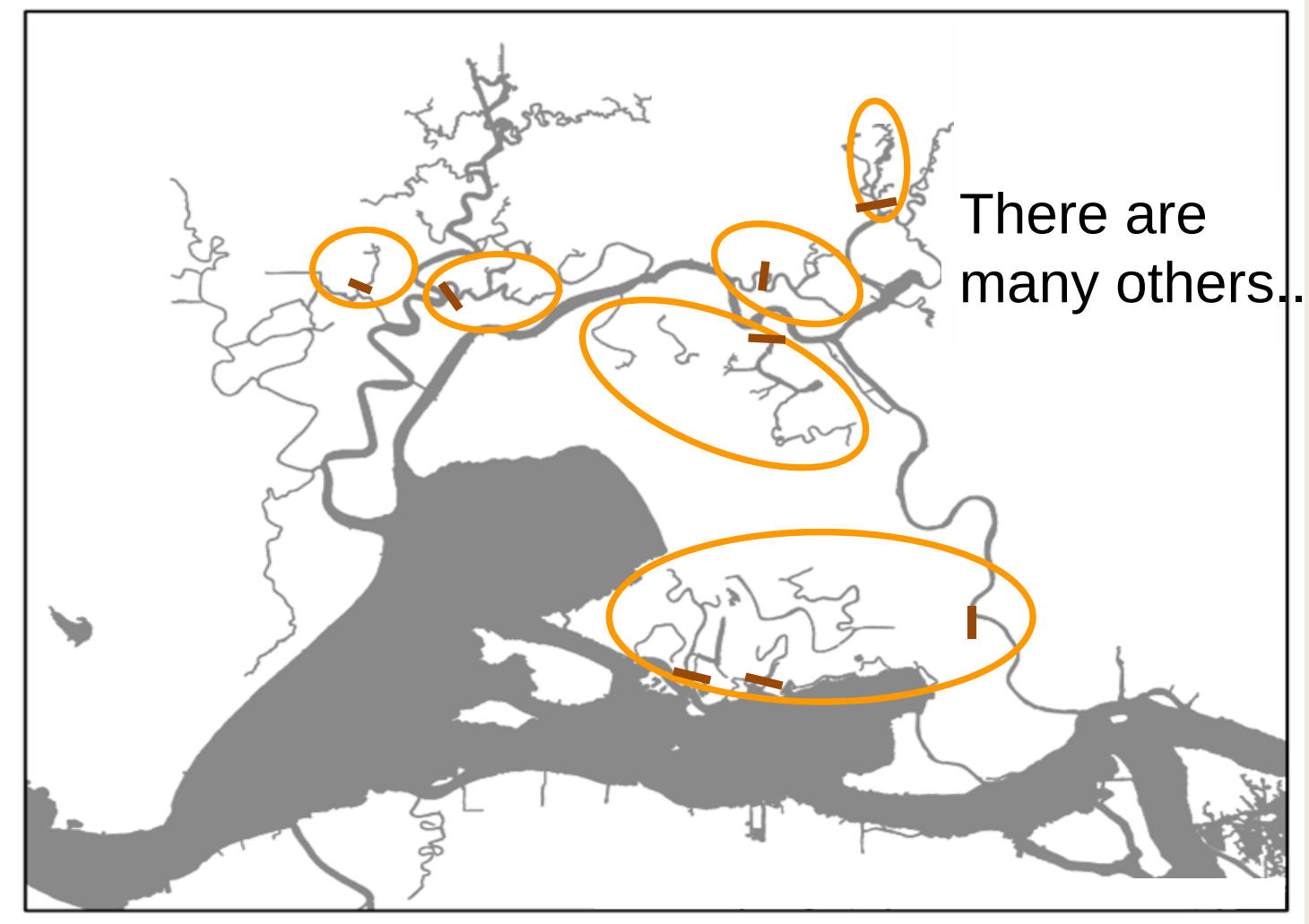
4. Implications for restoration

4. Implications for restoration

- Reduce the distance to different (e.g. Chipps Is.)

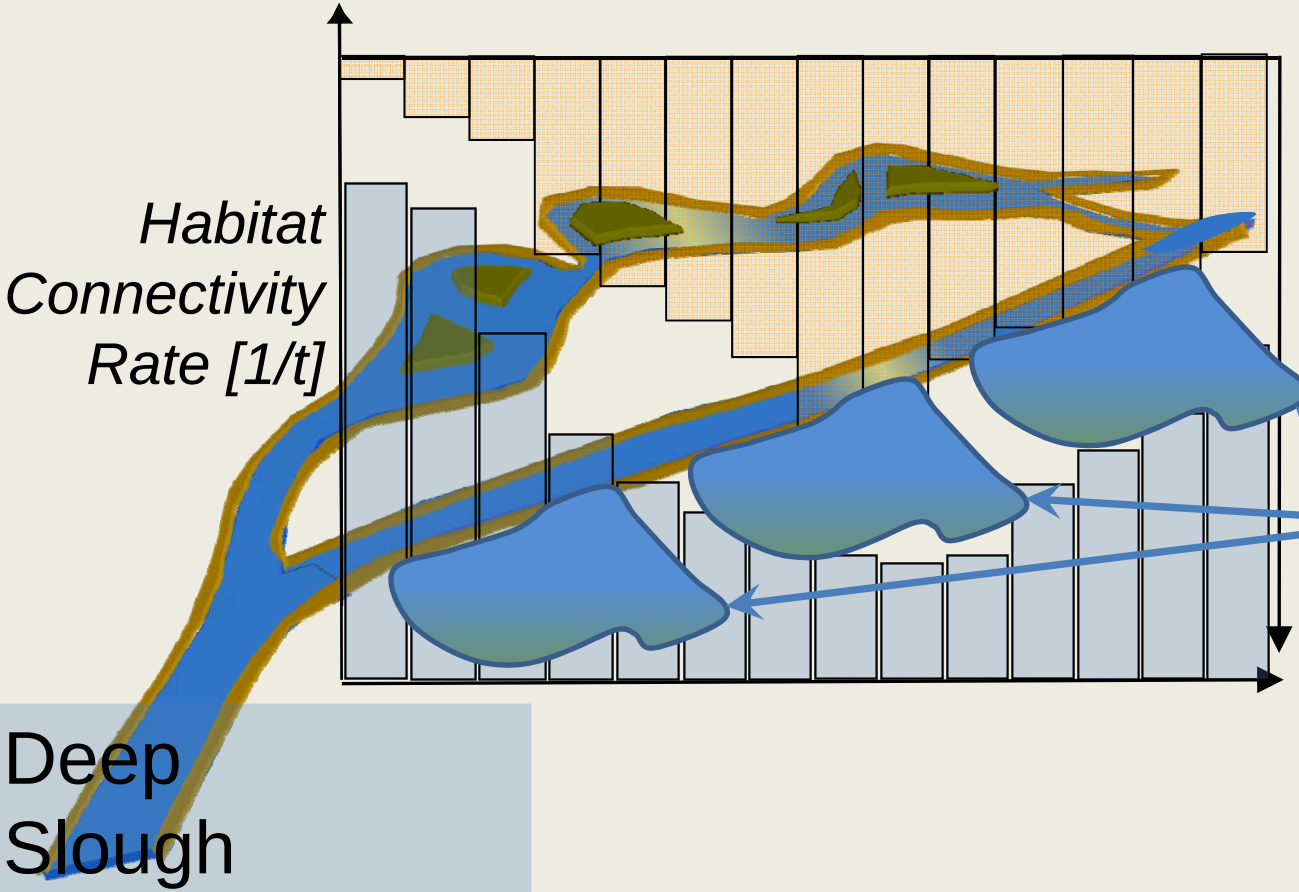
4. Implications for restoration

- Use historical structure as energy/material conduits.



4. Implications for restoration

- Provide for variable habitat connectivity



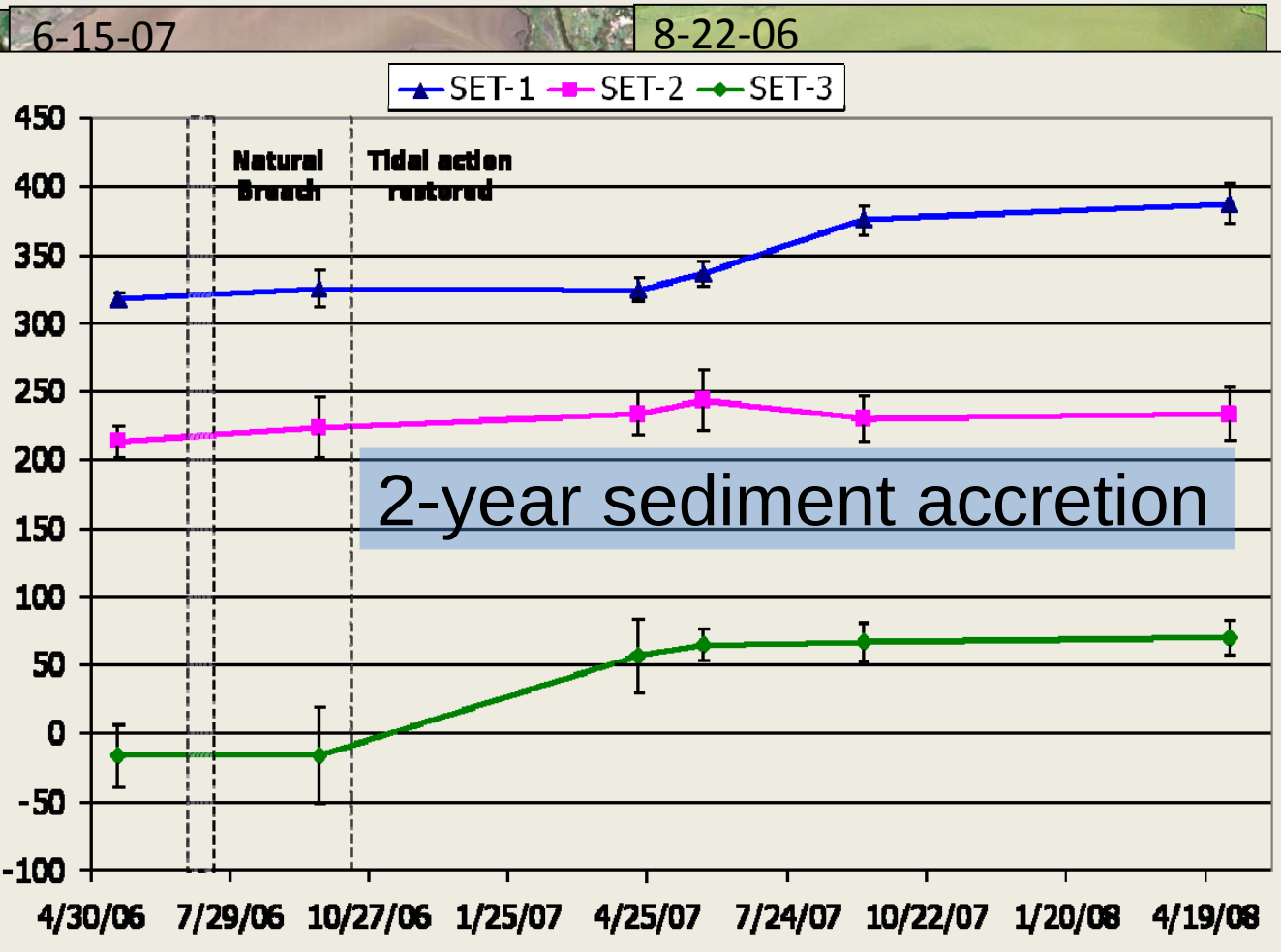
Restored ~autotrophic habitat

Deep Slough (~heterotrophic habitat)

4. Implications for restoration

- Use natural processes to advantage:

"Work with nature, let nature do the work"



Blacklock prop
Near end of eb

Key ideas

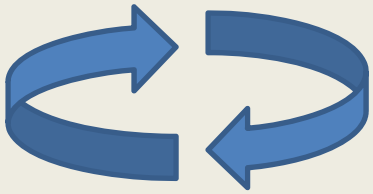
- Historical Delta was narrower, longer, way more ecotone.
- Structural relationships produced a gradient rich system.
- Native species need multiple forage, refuge, ontogeny options.
- Restored marshes should be productive and accessible at multiple scales.
- Learn how to use the levee breach “knob” to restore diverse structures, processes, and disturbances.
- **We know enough. Proceed boldly, watch closely, adapt if needed, teach the kids what we learn.**

Thank you

- Stuart Seigel, Jon Burau, Cliff Dahm, Leo Winternitz, Dave Harlow, Curt Schmutte, Carl Wilcox, Matt Nobriga, Paul Massera, Terri Fong

Why are we here (do I think)?

Species conservation affects water supply reliability

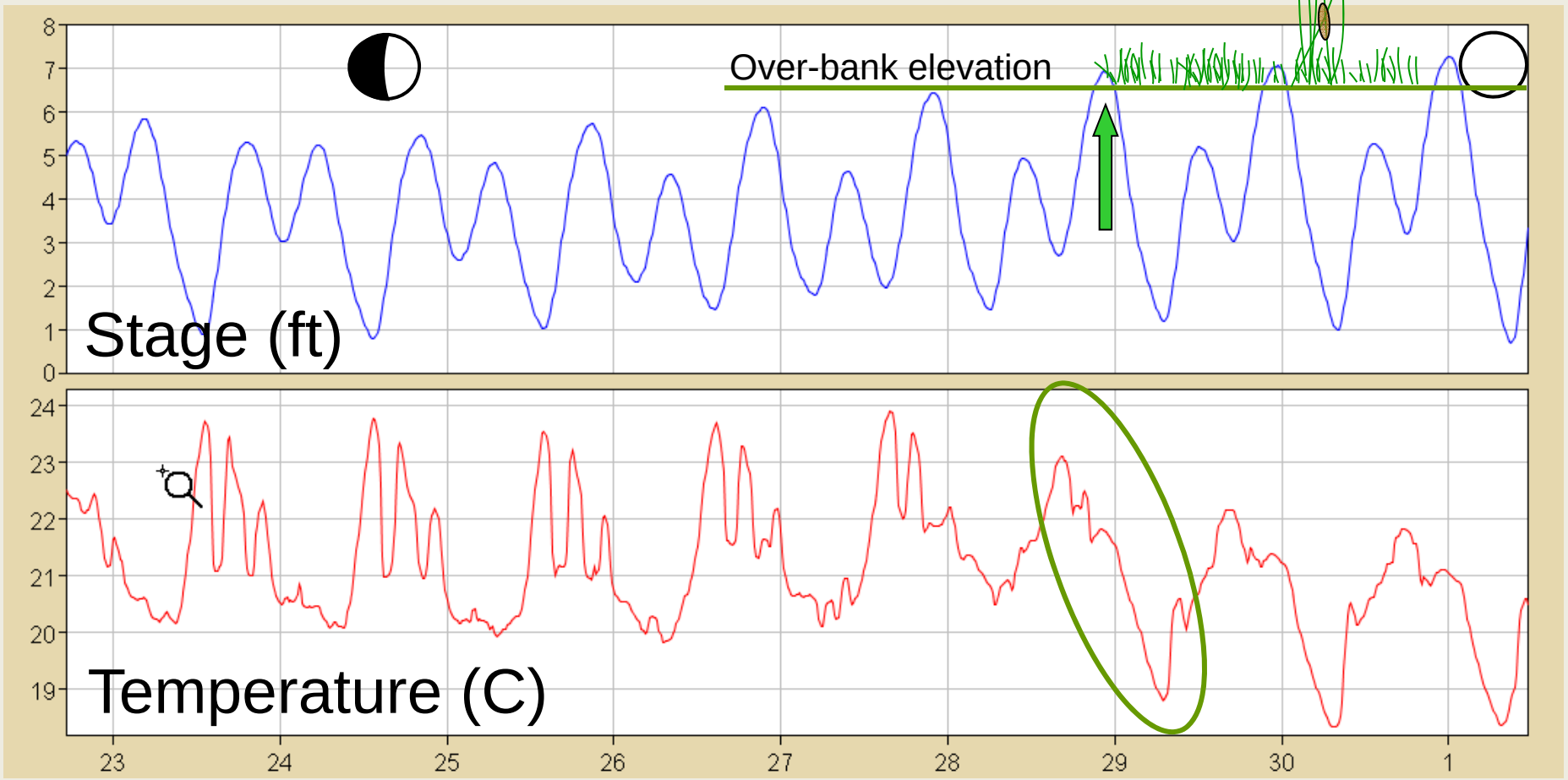


Water supply reliability affects species conservation

Therefore, set co-equal goals:

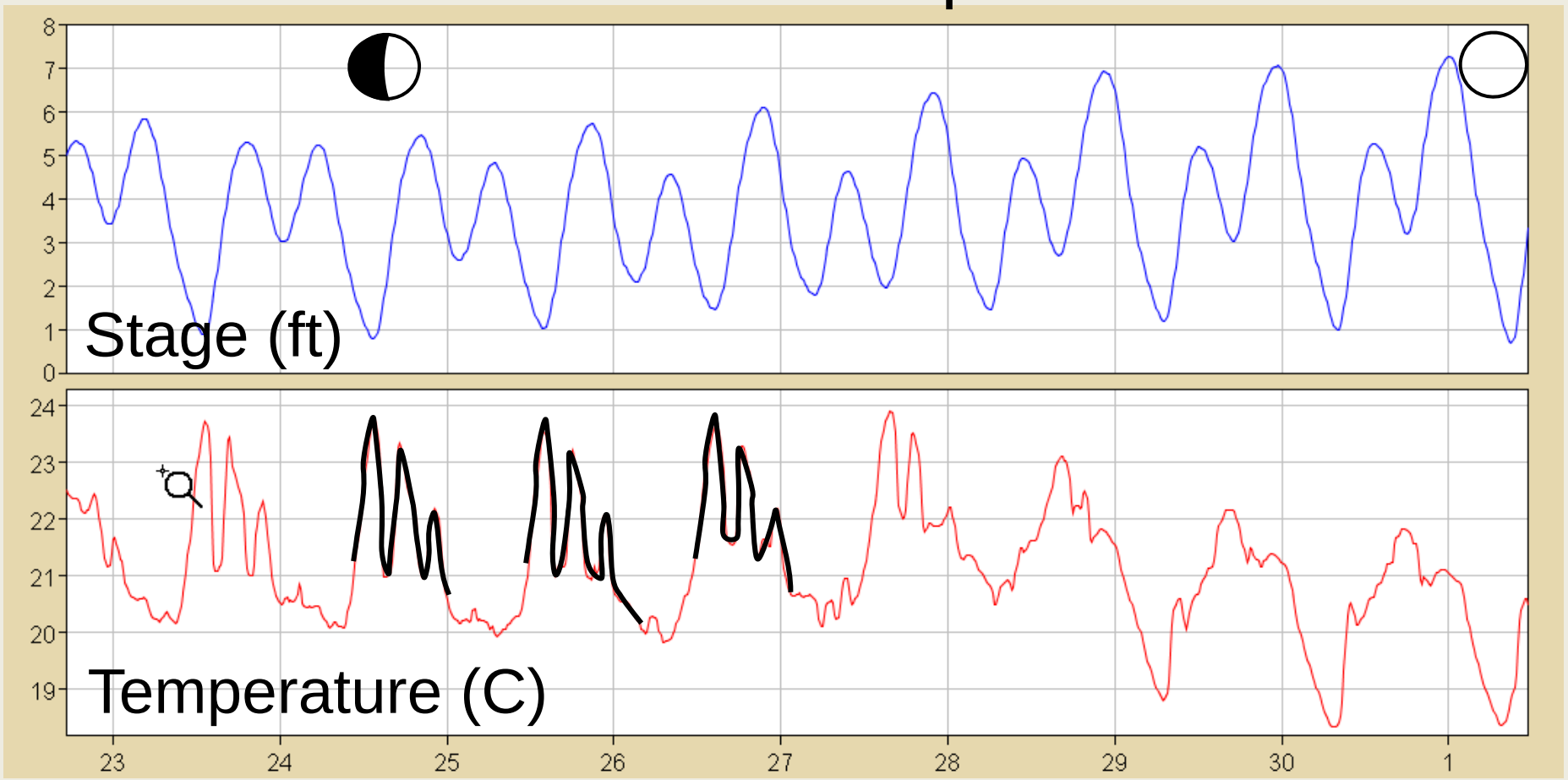
Increase water supply reliability *and* **conserve listed species (with ecosystem restoration)**

Structure controls functional variability: Structural disturbance thresholds



End of June 2004

Structure controls functional variability: Distance to different temperature is small



End of June 2004